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WASTEWATER TREATMENT PLANT ENVIRONMENTAL STUDY HOWARD AIR FORCE BASE, PANAMA

Michael F. Hewitt
Carlos A. Ortiz

Engineering-Science, Incorporated
57 Executive Park South N.E., Suite 500
Atlanta, Georgia 30329-2265

OCCUPATIONAL AND ENVIRONMENTAL HEALTH DIRECTORATE
2402 E Drive
Brooks Air Force Base, TX 78235-5114

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Carlos A. Ortiz

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57 Executive Park South N.E., Suite 500
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John G. Garland III

JOHN G. GARLAND III, LtCol, USAF, BSC
Contract Project Officer

J. Montgomery

JAMES D. MONTGOMERY, LtCol, USAF, BSC,
Chief, Bioenvironmental Engineering Division

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CHAPTER 1
INTRODUCTION TO THE HOWARD AIR FORCE BASE WASTEWATER TREATMENT SYSTEM

1.1 INTRODUCTION

This volume has been prepared for the operations and maintenance staff for the purpose of successfully operating the Howard Air Force Base wastewater treatment plant. This manual is intended to serve both as a training resource and as a routinely used guide to assist in the day-to-day operation and maintenance of the treatment facility.

The specific purpose of this manual is to provide the information necessary for plant personnel to make proper decisions that will insure successful operation of the plant. This manual fulfills this goal by: (1) acquainting personnel with the overall capabilities of the equipment; (2) instructing them on the purpose and intended operation of each process; and (3) providing them with the necessary instructions for the proper operation and maintenance of the facility.

The chapters of the O&M Manual are an attempt to provide complete and straightforward descriptions of the fundamental concepts related to the treatment facility. It is hoped that through frequent and routine use of the manual, plant personnel will become thoroughly familiar with the fundamentals presented and will be able to identify problems and determine a course of action for their solution. No manual, however complete and well prepared, can replace good judgment on the part of plant personnel in ensuring successful operation of the wastewater treatment facility. There are far too many possible problems and situations that the operations and maintenance staff will have to face for any such document to cover them all in detail.

The organization of this material is intended to make it easy to find desired information and keep it up to date. The format and use of a numerical outline will allow selected portions of the manual to be easily revised and updated. New chapters can be added or existing chapters expanded without affecting the remainder of the document. No manual written without the benefit of actual operating experience and input from the plant operators will be either complete or entirely correct. It is hoped that these chapters will be periodically updated to keep them current and maintain their usefulness. Review and comments from the plant operating personnel are essential to the usefulness of the O&M manual.

Operators should also utilize other resources available to them when making operational decisions. These include plans and specifications, vendor supplied materials and relevant training materials. References to these materials will be made throughout the O&M manual.

1.2 GENERAL PROCESS DESCRIPTION

The Howard AFB wastewater treatment plant is a biological treatment system employing the activated sludge process to achieve secondary treatment levels. The plant employs primary and secondary treatment processes, sludge stabilization and sludge dewatering processes. The treatment plant is designed to treat an average daily wastewater flow of 1.25 million gallons per day (MGD). The treatment plant's most recent major modification occurred in 1972-1974.

1.2.1 Major Treatment Units

The major treatment units at the Howard AFB wastewater treatment plant are:

- Screening (Bar Screen and Comminutor)
- Grit Chamber
- Biological Treatment (Activated Sludge)
- Secondary Clarifiers
- Aerobic Digesters
- Drying Beds
- Disinfection (Chlorination)

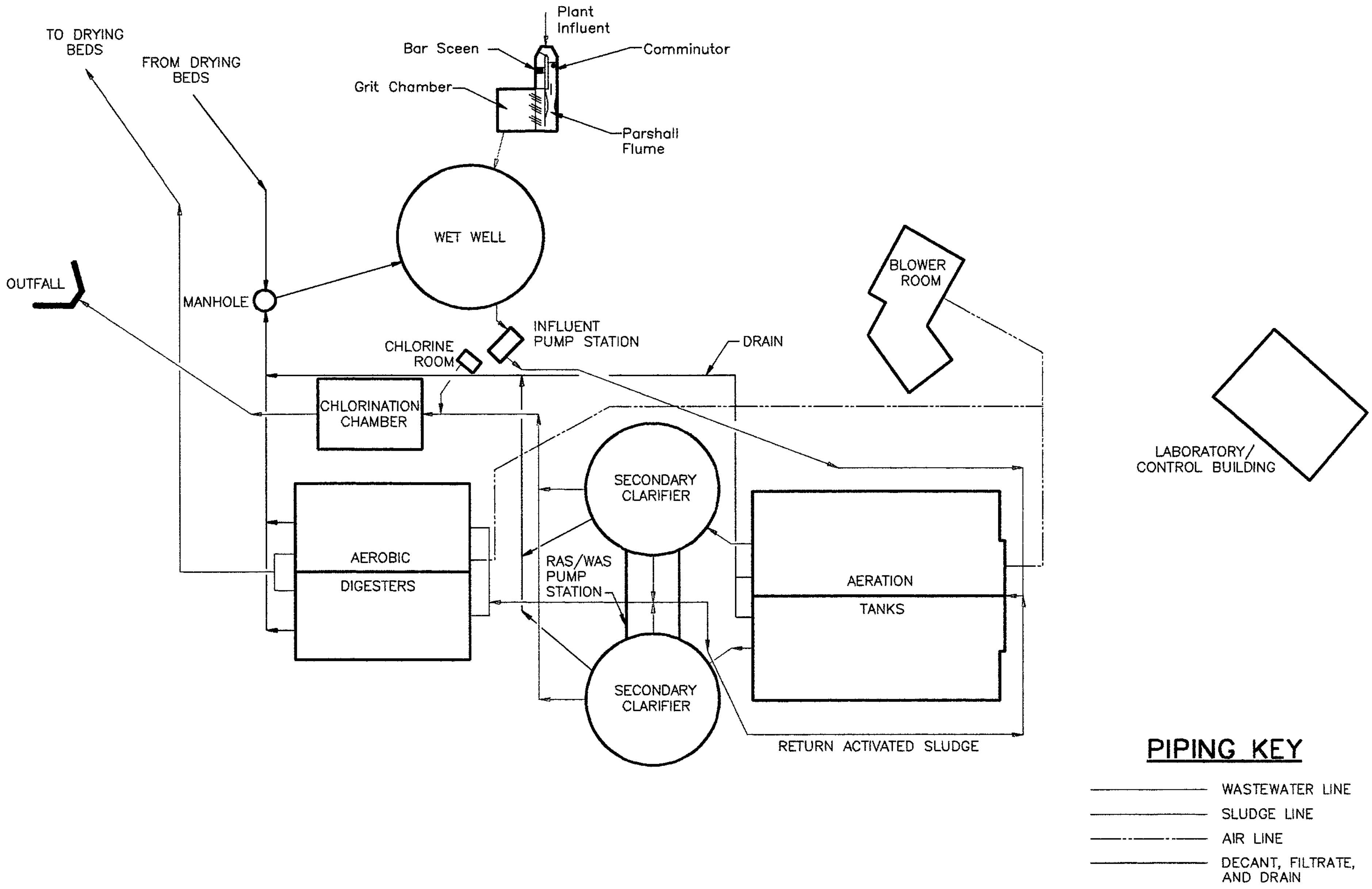
Figure 1.1 presents a flow schematic of the Howard AFB Wastewater Treatment Plant (WWTP). Major unit processes and flow streams are identified in the schematic.

In addition to the wastewater treatment plant, the operations and maintenance staff are responsible for the operation of seven lift stations located throughout the Howard AFB. These lift stations are identified and located as follows:

- Station 718 - Mulvehill Avenue at Bryant Avenue
- Station 225 - Mulvehill Avenue near Passenger Terminal
- Station 49 - Suliber Avenue at Andrews Blvd.
- Station 8 - South Corner of Motor Pool
- Station 1 - Behind Civil Engineering Building
- Station 949 - Beard Road
- Station 735 - Andrews Blvd. and Bryant Avenue

FLOW SCHEMATIC

HOWARD AIR FORCE BASE WASTEWATER TREATMENT PLANT



1.3 OPERATOR AND MANAGEMENT RESPONSIBILITY

1.3.1 Operator Responsibility

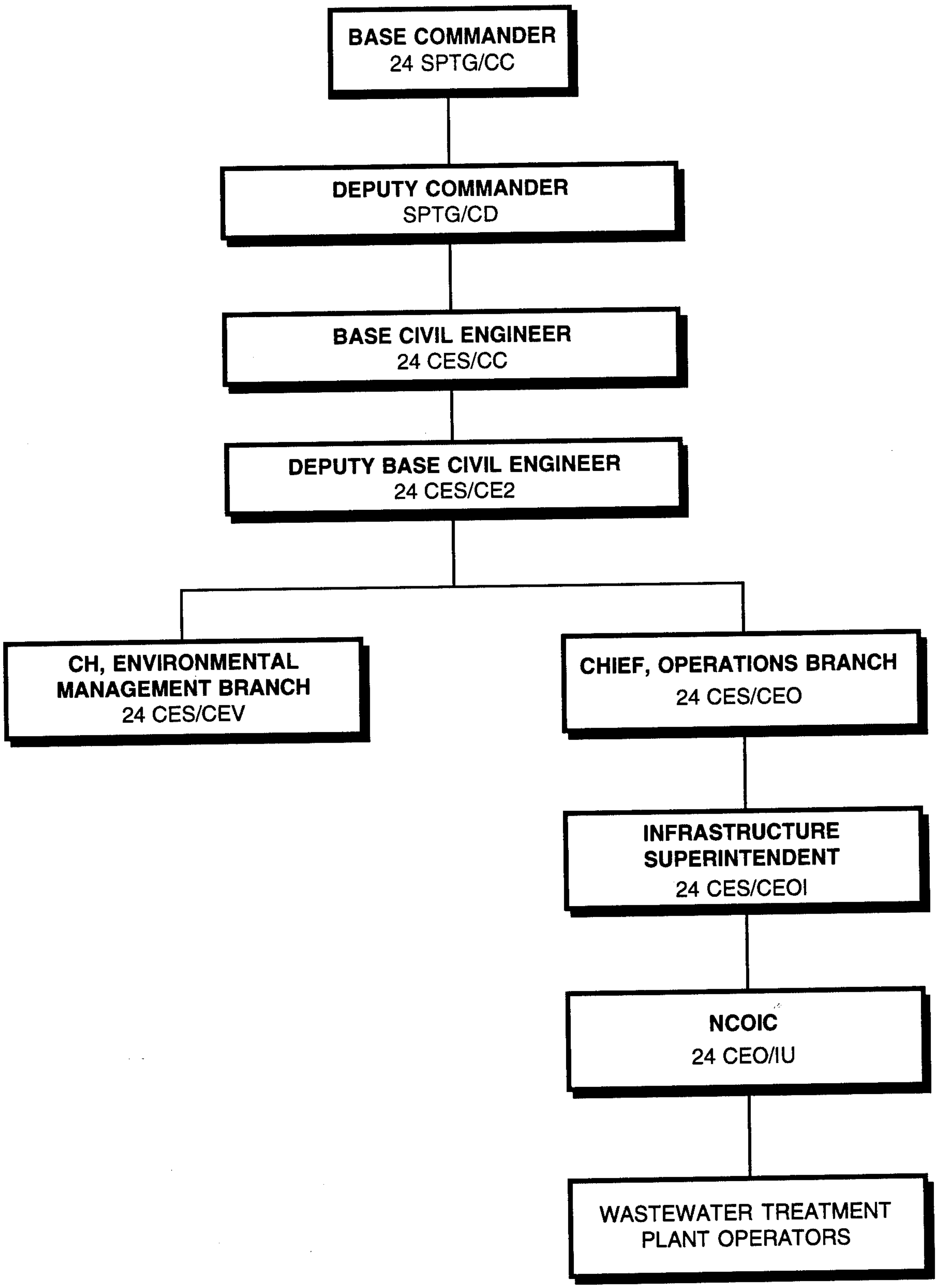
Great sums of public funds have been invested in many large and complex wastewater treatment facilities to meet the discharge requirements necessary to maintain and protect the environment. Because of their function, the wastewater treatment plant operators play a key role in pollution control. Without efficient operation of each facility, the research, planning, and construction that has been done to accomplish the goals of water quality control will be wasted. Thus, the treatment plant operator can make the difference between pollution control equipment which is performing just adequately or excellently. Operators have a very responsible and important position since they are the only ones who control how well the wastewater will be treated before it is discharged into the environment.

The Howard AFB operators are responsible for the overall operation and maintenance of the WWTP. Their duties encompass all activities of the WWTP and in other areas, such as lift stations.

1.3.2 Management Responsibility

Management of the Howard AFB wastewater plant, including the Chief of the Operations Branch of Civil Engineering, Infrastructure Superintendent, Non-Commissioned Officer-in-Charge (NCOIC) have responsibility for providing administrative and supervisory control over the operation and maintenance of the treatment system. These responsibilities include supervisory direction, personnel management and coordination with other on-base support services. Management is also responsible for ensuring effective communication among all personnel, encouraging operational suggestions, and marshaling the necessary resources for needed projects at the WWTP. Figure 1.2 provides an organization chart for the Howard AFB WWTP.

HOWARD AFB WWTP ORGANIZATIONAL CHART



1.4 OPERATOR TRAINING AND SELECTED REFERENCE MATERIALS

The operators at the Howard AFB wastewater treatment plant are exposed to a number of training programs. The majority of these programs are safety oriented.

To enhance a self-study program, a number of more advanced materials specific to the Howard AFB wastewater treatment plant should be obtained for use by the operators. Recommended references from the Water Environment Federation (former Water Pollution Control Federation) include:

- Manual of Practice 7 - Operation and Maintenance of Wastewater Collection Systems
- Manual of Practice OM-3 - Plant Maintenance Program
- Manual of Practice MOP-16 - Anaerobic Sludge Digestion
- Manual of Practice 11 - Operation of Wastewater Treatment Plants
- Manual of Practice OM-1 - Wastewater Sampling for Process and Quality Control

In addition to the above self-study materials, it is recommended that the following approaches to operator training be adopted at the Howard AFB wastewater treatment plant:

- An in-house training program utilizing plant personnel and base resources focused on specific plant processes and treatment related subjects should be adopted. Classes should be held on at least a monthly basis.
- Attendance at outside training schools or training courses provided by outside trainers should be encouraged to the extent possible within budget constraints.
- Informal group study sessions among the operators during shift hours should be encouraged to promote discussion and interest in the operation of the wastewater plant.
- Within budget constraints, operators should participate in correspondence course training offered by California State University at Sacramento.

As an additional aspect of the training program, the wastewater operators should have access to various periodicals pertaining to wastewater treatment. Among the recommended periodicals are:

- "Operations Forum", a publication of the Professional Wastewater Operations Division of the Water Environment Federation.
- "Water Environment and Technology".

1.5 PERMITS

The Howard AFB WWTP is designed to be in compliance with the Overseas Environmental Baseline Guidance Document criteria. The Howard AFB WWTP discharges to an unnamed tributary which discharges to the outfall ditch at Venano Beach. The overseas guidance criteria are presented in Table 1.1.

In addition to the criteria presented in Table 1.1., general operating requirements which should be followed are summarized below. These requirements are not listed in the criteria document but are those usually required by National Pollutant Discharge Elimination System Permits at US Air Force installations in the U.S.

1. The plant should have a continuous recording flow monitoring system capable of measuring and recording the total and maximum daily flow.
2. Influent samples must be collected and analyzed for BOD, Total Suspended Solids and pH at the same frequency as required for the effluent.
3. Semiannual sampling and analysis of the influent, effluent and sludge should be performed for metals and priority pollutants.
4. Samples and measurements shall be representative of the volume and nature of the discharge. Sludge samples shall be collected at a location representative of the quality of sludge being disposed.
5. Records of monitoring data shall be maintained including the date, exact place, and time of sampling or measurement, the initials of the person performing the measurement, the dates and times the analyses were performed, a reference to the written procedure used and the raw data and final result of the analyses.
6. The plant is to be properly operated and maintained including all installed equipment used to achieve compliance. Proper O&M includes adequate laboratory controls and quality assurance measures.
7. Removed substances such as sludge, grit and screenings must be properly disposed of so as to not cause pollution or a health hazard.
8. Industrial waste management should be fully implemented to prevent the discharge of pollutants into the plant which are prohibited, which interfere or pass through the plant or which exceed pretreatment standards.

TABLE 1.1

Overseas Environmental Baseline Guidance Document Criteria

Parameter	Units	30-Day Average	7-Day Average	Daily Maximum	Daily Minimum
Biochemical Oxygen Demand (5-day)	mg/l	45	65	--	--
Suspended Solids	mg/l	45	65	--	--
Fecal Coliform*	Colonies/ 100 ml	--	monitoring only	--	--
pH	Standard Units	--	--	9.0	6.0

* - Fecal Coliform monitoring requirements were added as a recommendation following an ECAMP inspection.

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1.6 PERSONNEL REQUIREMENTS

1.6.1 Certification Program

The Howard AFB is the only activated sludge wastewater treatment plant in the Panama Canal Zone. Currently, there are no requirements for operator certification and training. It is recommended that a training standard be developed for the civilian operators. This might be accomplished through the Canal Zone Merit System Qualification Standard for the Wastewater Treatment Plant Operator position. A correspondence course such as "Operation of Wastewater Treatment Plants" offered by the California State University at Sacramento would be an excellent course to utilize as the standard. This course could be implemented for training of plant operators either in a correspondence course, self-study format or by utilizing in-house instruction and supervised examination (1.4.1.6).

1.6.2 Manpower Requirements

The Howard AFB WWTP is staffed by one Non-Commissioned Officer In Charge (NCOIC), one assistant operations foreman, two shift supervisors, one maintenance mechanic and five operators. One of the operators is military and four are civilians. The overall management of the wastewater treatment plant is directed by the Infrastructure Superintendent and above that position is the Chief of the Operations Branch of Civil Engineering. In addition to the wastewater treatment plant and laboratory, the O&M personnel are responsible for seven lift stations, four water booster stations and two swimming pools. Civilian operators spend approximately 65% of their time on activities related directly to the wastewater treatment plant or laboratory due to their other responsibilities. The maintenance mechanic is approximately 35% available for plant maintenance. The military operator has approximately 65% utilization on plant O&M. The NCOIC is approximately 42 percent available for plant O&M supervision after taking into consideration his military and off-plant responsibilities. This results in a total available manpower of six full-time persons for the wastewater treatment. The plant should be staffed 24 hours per day.

CHAPTER 2
DESCRIPTION OF FACILITY

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DESCRIPTION OF FACILITY

2.1 INTRODUCTION

The purpose of this chapter is to provide a thorough description of the processes and equipment at the Howard AFB wastewater treatment plant. This description is designed to present a general understanding of the systems involved in the plant, how they function, and how they are interrelated. Some numbers regarding the equipment sizes and capacities are included when necessary.

2.1.1 General

The Howard AFB wastewater treatment plant consists of a biological treatment system employing the activated sludge process to achieve secondary treatment levels. The plant utilizes preliminary and secondary treatment processes. Sludge stabilization and dewatering processes are also provided. A flow schematic of the Howard AFB WWTP was provided in Figure 1.1.

2.2 COLLECTION SYSTEM AND LIFT STATIONS

The Howard AFB wastewater treatment plant (WWTP) is located in the southwest portion of the base property. Flow to the WWTP is through force mains and a series of lift stations located throughout the base. The major sources of wastewater flow to the WWTP are:

- Base housing area
- The main base area
- Flightline area

Non-domestic wastewater from shops on the flightline contribute approximately one percent of the flow to the WWTP. There are seven (7) remote lift stations located throughout the base. The lift stations are located as follows:

- Station 718 Mulvehill and Bryant Avenues
- Station 225 Mulvehill Avenue
- Station 49 Suliber Avenue at Andrews Blvd.
- Station 8 South Corner of Motor Pool
- Station 1 Rear of Civil Engineering Bldg.
- Station 949 Beard Road
- Station 735 Andrews Blvd. and Bryant Avenue

2.3 PRELIMINARY TREATMENT

The preliminary treatment processes employed at the Howard AFB WWTP are comminution, flow measurement, grit removal, manual screening and influent pumping.

2.3.1 Plant Headworks

Raw wastewater enters the treatment plant through an 18-in pipe to a 12-in channel provided with a comminutor. A 9-in Parshall flume with an ultrasonic sensor is located approximately 7 ft downstream of the comminutor to measure the influent flow. The ultrasonic signal is sent to a local flow meter and a totalizer. The totalizer is located in the laboratory/control building.

An alternate channel can be selected by changing slide gates to bypass the comminutor and Parshall flume. The channel contains a 18 inch manual bar screen with 1.25 inch bar spacing.

2.3.2 Grit Chamber

Forward influent flow continues from the Parshall flume to a horizontal grit chamber. Grit which settles in the bottom of the chamber is moved by a rotating rake mechanism to a sump at the side of the chamber, from which it is removed by a screw conveyor. The screw conveyor is controlled manually and discharges into a 50-gal drum. The contents of this drum are disposed of by burial in the Redtank Landfill. The wastewater flow continues from the grit chamber to the influent wet well, passing through a manual bar screen with 2-inch wide openings. Screenings are removed manually with a rake (7-9 times a day), put into the grit storage drum and disposed of at the Redtank Landfill.

2.3.3 Influent Pump Station

The influent pump station has a wet well and two vertical variable speed pumps. The influent wet well is a modified Imhoff tank. The bottom of the original structure has been filled up with sand and topped with a 4-in concrete slab. The storage capacity of the wet well is approximately 88,850 gal. Each pump delivers a maximum flow of 1,000 gpm. At the time of this writing, the variable speed drives were not functioning and the pumps were operating at their maximum capacity.

2.4 AERATION BASINS

The WWTP is provided with two aeration tanks for the biological treatment of organic wastes. The pretreated influent enters a splitter box, where it is mixed with the return activated sludge (RAS). Each aeration tank has a rectangular section of 55.5 ft by 25 ft and a side water depth (SWD) of 15 ft, for a hydraulic capacity of approximately 159,400 gal. The total aeration basin volume is 318,800 gallons. The average loading rates to the system are as follows:

Hydraulic Loading Rate 344 gpd/ft2

Volumetric Organic Loading Rate 22.2 lb BOD/1,000 ft3

The volumetric organic loading rate is in the lower end of the recommended design range for conventional activated sludge systems (i.e., 18.7 to 37.5 lb BOD/10003-d). Flow enters the aeration basin from the influent pump station via a 10 inch force main. This force main joins the return sludge flow in a 16 inch line which flows into the aeration basin splitter box.

Flow into and out of the aeration basin is controlled by slide gates. Slide gates in the splitter box at the head end of the aeration basin structure allow flow to one or both basins. Slide gates at the discharge channel allow flow from either or both basins to be directed to individual clarifiers. Diffused air is applied to maintain aerobic conditions and to provide mixing by two 200 horse-power centrifugal blowers and subsurface fine bubble diffusers. The diffusers are located on riser pipes emanating from three distribution headers in each tank. Each tank is equipped with drain valves for emptying the basin contents to the influent wet well.

2.5 SECONDARY CLARIFIERS

Two circular center feed secondary clarifiers are provided for the settling of biological sludge. The discharge from the aeration tanks flows to the secondary clarifiers through a wide-crest weir, a 1.5 ft trough and 18-inch pipes. The trough is equipped with a slide gates for flow distribution. The content of each aeration tank can be discharged separately to the corresponding clarifier if required.

The units are 35 feet in diameter and have a SWD of 8.5 feet. The clarifiers are equipped with motorized rake arms for pushing sludge to center hoppers. The sludge is returned to the aeration basins or wasted to the digesters. The raking mechanisms also utilize surface skimmers which push scum and foam to scum boxes mounted on the periphery of the clarifiers. The scum is pumped to the digesters by the waste sludge pumps. A collection trough around the perimeter of each clarifier receives the effluent which flows into the 18 inch secondary clarifier effluent line. The secondary clarifier effluent flows to the chlorine contact chamber. Current available surface area for both units combined is 1924 ft2. Current available volume is 122,340 gallons. Operating parameters for the secondary clarifiers under average flow conditions are as follows:

Surface loading rate	492 gpd/ft2
Solids loading rate	4.54 lb TSS/ft2-d
Hydraulic retention time	3.1 hours

2.6 RAS/WAS PUMP STATION

The Return Activated Sludge (RAS)/Waste Activated Sludge (WAS) Pump Station is located between the secondary clarifier at ground level. There are three 500 gpm RAS pumps with variable speed drive. Normally one pump each is dedicated to one of the secondary clarifiers and the third pump provides back up. Return sludge is pumped from the secondary clarifiers to the head of the aeration basins via an eight inch force main. The WAS pumps draw sludge or scum from the clarifiers and pump it to the aerobic digesters via a 4 inch force main.

2.7 CHLORINE CONTACT CHAMBER

The WWTP is equipped with a chlorine contact chamber which receives flow from the secondary clarifiers. The chamber is 20 feet long, 16 feet wide and 8 feet deep. Its length-to-width ratio is 1.25. Baffle walls direct the flow in an upward-downward pattern throughout its length. At average flow conditions, the basin has a hydraulic retention time of 28 minutes.

Chlorine gas is fed through one, 100 pound per day wall-mounted chlorinator. Chlorine injection into the basin is accomplished using a pipe which routes chlorine solution into the head of the basin. An average of 40 pounds of chlorine gas per day is being fed to disinfect the effluent and is resulting in an average total chlorine residual in the effluent of 0.25 mg/L. There are no limits or requirements on the effluent chlorine residual at the Howard AFB WWTP. Chlorine gas feed control is manual. Plant operators take samples which are analyzed for Total Chlorine Residual. These data are used to make adjustment in the chlorine feed rate. Effluent from the chlorine contact chamber flows by gravity through an 18 inch line to the plant outfall discharge. The discharge flows by open ditch to Venano Beach.

2.8 AEROBIC DIGESTERS

The Howard AFB WWTP is equipped with two aerobic digesters. Each unit has a surface area of 800 ft2 (40' x 20') and a 15.5-ft SWD for a unit volume of 92,750 gal. The total volume of the two units is 185,500 gallons. Diffused air is provided to maintain aerobic conditions and mixing level requirements. Air diffusion rates are controlled by air control valves on the air header pipes running the length of the digesters.

The average WAS flow to the digesters is approximately 15,400 gpd and the average solids concentration is 2,870 mg/L. Therefore, the current loading factor is approximately 0.012 lb TSS/ft3-d. This loading level is below the design range for aerobic digesters (i.e., 0.024-0.14 lb solids/ft3-d).

The average retention time for digestion is approximately 45 days. Since the hydraulic capacity of the digesters can provide a total retention time of 12 days, it is necessary to decant and concentrate the sludge. The digesters are equipped with decant and drain valves which direct flow to the influent pump station wet well. Control of the digesters is currently based on volatile solids reduction. Sludge is digested until a 40% decrease in volatile solids is achieved.

2.9 SLUDGE DRYING BEDS

The Howard AFB WWTP utilizes sludge drying beds to dewater the plant sludge after its stabilization by aerobic digestion. There are four covered drying beds. Each is 120 feet long by 25 feet wide. Sludge is normally drawn unto the beds at a depth of 8-12 inches. At 12 inches of sludge depth, the four beds constitute a total sludge volume of approximately 90,000 gallons. The four beds can accommodate the volume of one aerobic digester.

Sludge flows by gravity from valves in the bottom of the digester through a 6 inch header. The header pipe runs in front of the beds and sludge flow into individual beds is controlled by gate valves. The beds contain a 4-6 inch layer of sand, followed by 12 inches of gravel, under which is drain tile. Filtrate flows down through the media and tile and into a 6 inch filtrate return line. The drying bed filtrate flows to the influent pump station wet well.

CHAPTER 3
THEORY OF OPERATION OF UNIT PROCESSES

CHAPTER 3
THEORY OF OPERATION OF UNIT PROCESSES

3.1 PRELIMINARY TREATMENT

3.1.1 Introduction

Incoming wastewater to a treatment plant contains a very diverse blend of constituents. Coarse materials such as string, rags, paper, cans, and wood can enter a plant through the sewer system. Wastewater also contains a relatively large amount of inorganic solids such as sand, gravel, and cinders which are collectively called grit. Besides being unaffected by biological treatment, materials such as the above can damage pumps and other equipment as well as plug pipelines. Removal of these materials helps to prevent disruption of downstream processes and to protect equipment. The Howard AFB WWTP contains several preliminary treatment processes designed to remove these materials.

3.1.2 Screening

Screening was one of the first methods used to remove large solids from wastewater. The main purpose of many of the first wastewater plants was to only remove the visible, large solids. Coarse screens are normally employed as the first treatment unit for the primary purpose of protecting plant equipment from physical damage or reduced operating efficiency.

3.1.3 Grinders and Comminutors

Grinders and comminutors are used to reduce the particle size of screenings to a size that will not clog pumps. They are frequently incorporated in facilities to eliminate the need for storing and separately disposing of screenings or to supplement the screening process. For this reason, they tend to reduce odors and unsightliness on the plant site. Comminutors and grinders do have several drawbacks. Among these are rag accumulations on downstream equipment and the tendency to create "ropes" of the material it has ground up.

3.1.4 Grit Removal

The function of grit chambers is to remove large inorganic solids such as sand, gravel or cinders. They are designed to remove solid materials that have subsiding velocities or specific gravities substantially greater than those of the organic solids in

wastewater. Most grit chambers are constructed to capture particles with a specific gravity greater than 2.65 and a diameter larger than 0.02 centimeters.

The objective of grit removal is to remove the inorganics from the wastewater flow with a minimum of organic materials also being removed. If flow rate through a grit chamber is too high, little inorganic material will settle out. If flow rate is too low a large amount of organic matter will settle out with the grit. Excessive organic matter in the grit leads to more frequent cleaning of the grit chambers and can lead to odor problems while the grit is stored awaiting disposal.

3.1.5 Grit Collection

Accumulation of settled grit at the bottom of grit chambers must be removed regularly. If cleaning is ignored the efficiency of the unit will decline and cause unwanted material to pass into the plant. At the Howard WWTP, grit settles in a horizontal grit chamber, is raked by a rotating mechanism to a sump and is then removed by a screw conveyor. The age and operational condition of the grit screw at the Howard AFB WWTP has at times necessitated the use of a suction truck to remove grit from the grit chamber.

3.1.6 Grit Disposal

The different methods of grit disposal include sanitary landfills, lagoons, and land spreading. In general, it is best to bury and cover the grit, as the residual organic content can still be a nuisance. Since grit has good structural stability, it will not cause problems with future use of the land. The grit may be combined with other waste solids from the treatment plant before disposal. The Howard AFB WWTP grit is currently disposed of by on-site burial and landfilling.

3.2 BIOLOGICAL TREATMENT PROCESS

3.2.1 Introduction

Biological treatment is the most important step in processing domestic wastewater. Physical treatment of wastewater by sedimentation only removes about 35 percent of the biochemical oxygen demand (BOD) due to a high percentage of non-settleable organic solids (colloidal and dissolved) in domestic wastes. Chemical treatment alone is not favored because of high costs. A modern treatment plant uses a variety of physical, chemical, and biological processes to provide the best, most economical treatment.

Biological treatment systems are "living" systems which rely on mixed biological cultures to break down waste organics and remove organic matter from solution. Domestic wastewater supplies the biological food and growth nutrients. A treatment unit provides a controlled environment for the desired biological process.

Wastewater treatment operations contain communities of microorganisms made up of populations of individual species. Within the community, changes can occur in populations present as the system responds to changes in the quantity and character of the material entering in the feed stream, or to changes in the physical environment. If the nature of the waste being treated is such that it supports a broad and diverse microbial community, the community will adapt readily to changing environmental conditions, and the system will appear fairly stable from the microscopic point of view. Under some circumstances the community may be restricted. This leads to an unstable biochemical environment and a process which is difficult to control. Generally, complex integrated communities with a large number of diverse species are considered to be healthy ecosystems.

3.2.2 Microorganisms in Biological Systems

3.2.2.1 Bacteria

Bacteria are the simplest forms of plant life which can use soluble food and are capable of self-reproduction. Bacteria are single-celled, independent organisms with each cell capable of carrying out all necessary functions of life. Bacteria are fundamental microorganisms in the stabilization of organic wastes and therefore of basic importance in biological treatment. Uncontrolled, bacterial decomposition of organic wastes can produce odors and objectionable conditions. In controlled environments, bacteria can stabilize organic matter and prevent objectionable conditions.

Based on nutrient requirements, bacteria are classified as heterotrophic or autotrophic, although several species may function both heterotrophically and autotrophically.

Heterotrophic bacteria use organic compounds as an energy and carbon source for synthesis. A term commonly used instead of heterotroph is saprophyte, which refers to an organism that lives on dead or decaying organic matter. The heterotrophic bacteria are grouped into three classifications depending on their action towards free oxygen. Aerobes require free dissolved oxygen to live and multiply. Anaerobes oxidize matter in the complete absence of dissolved oxygen. Facultative bacteria are a class of bacteria which use free dissolved oxygen when available but can also respire and multiply in its absence.

Autotrophic bacteria use carbon dioxide as a carbon source and use inorganic compounds for energy. Autotrophs of greatest significance in wastewater treatment are the denitrifying and sulfur bacteria.

Bacteria are also classified according to the temperatures at which they thrive. The largest proportion of saprophytes thrive at 20° to 40°C or 68° to 104°F and are called mesophilic types. Variations from this temperature range limit the activity of mesophilic bacteria, practically eliminating them at high and low temperatures. Other bacteria thrive at higher temperatures, in the range of 55 to 66°C or 130 to 140°F. These are known as thermophilic types. Very few types find their optimum temperatures at low temperatures (0 to 5°C or 32 to 40°F). These are known as psychrophylic bacteria. Mesophilic bacteria are important in all biological treatment systems. Thermophilic bacteria are important in some sludge digestion systems.

Bacteria have the ability to reproduce rapidly when in intimate contact with their nutrient material (i.e., wastes) and feed readily by taking in food directly through their cell walls. Bacteria occur in three basic shapes: rods (bacilli), spheres (cocci), and spirals. While all these forms are found in wastewater, quite often they are found individually enmeshed or associated in masses, slimes, or flocs. They are capable of growth in suspended or attached masses.

3.2.2.2 Fungi

Fungi are heterotrophic microorganisms which are predominantly filamentous (stringy) in nature and quite different in shape from the bacteria. Fungi are multi-cellular as opposed to the single-celled bacteria. Generally, fungi are somewhat larger than the bacteria and do not have a primary role in wastewater treatment. At times, certain fungi can cause serious interferences or nuisance problems in wastewater treatment, especially in settling. This generally occurs in low pH or low nitrogen environments.

3.2.2.3 Algae

Algae are microscopic autotrophic-photosynthetic plants. The process of photosynthesis is illustrated by the equation:

$$CO_2 + 2H_2O \underset{\text{dark reaction}}{\overset{\text{sunlight}}{\rightleftharpoons}} \text{New Cell Tissue} + O_2 + H_2O$$

Energy for photosynthesis is derived from sunlight. Photosynthetic pigments biochemically convert the energy in the sun's rays to useful energy for plant synthesis. The most common pigment is chlorophyll, which is green in color. Other pigments or combinations of pigments result in algae of a variety of colors, such as blue-green, yellowish green, brown, and red. In the prolonged absence of sunlight, the algae perform a dark reaction--for practical purposes the reverse of photosynthesis. In the dark reaction, the algae degrade stored food and their own protoplasm for energy to perform essential biochemical reactions for survival. The rate of this endogenous reaction is significantly slower than photosynthetic reaction.

There are a variety of algae forms that may be found. Raw wastewaters, unless exposed to sunlight, do not usually contain algae, while trickling filters and oxidation ponds have large numbers of algae in areas exposed to sunlight. Algae frequently play an important role in providing oxygen to stabilization ponds through photosynthesis. Because algae grow rapidly as a result of excess amounts of nutrient nitrogen and phosphorous (especially the latter), their excessive growth can be a source of nuisance problems in streams, lakes, ponds or other bodies of water. The most serious algae problems in receiving waters are associated with the growth of blue-green algae. Trickling filters, final settling tanks, discharge channels and receiving streams will

frequently have filamentous, attached green algae or brown diatoms at different times of the year.

3.2.2.4 Protozoa and Higher Animals

Protozoa are single-celled animals that reproduce by binary fission. The protozoa of significance in biological treatment systems are strict aerobes found in activated sludge systems, trickling filters plants and oxidation ponds. These microscopic animals have complex digestive systems and use solid organic matter as an energy and carbon source. Protozoa are a vital link in the aquatic food chain since they ingest bacteria and algae and are scavengers and predators in biological treatment processes.

A number of types of protozoa are common to biological processes such as activated sludge. Protozoa with cilia may be categorized as free-swimming and stalked. Free-swimming forms move rapidly in the water ingesting organic matter at a very high rate. The stalked forms attach by a stalk to particles of matter and use cilia to propel their head about and bring in food. Another group of protozoa move by flagella. Long hair-like strands (flagella) move with a whip-like action providing mobility. Amoeba move and ingest food through the action of a mobile protoplasm.

Rotifers are the simplest multicelled animals. They are strict aerobes and metabolize solid food. A typical rotifer uses the cilia around its head for catching food. The name rotifer is derived from the apparent rotating motion of the cilia on its head. Rotifers are indicators of low pollutional waters and are regularly found in streams and lakes.

3.2.3 Bacterial Utilization of Food

As stated earlier, bacteria in biological wastewater systems utilize the incoming waste for food. Bacteria can only use organic wastes which are in a soluble, or dissolved, state. Soluble organics are ingested directly through the cell wall and membrane by the bacteria for utilization. This process is known as absorption, or the taking up of one substance into the body of another.

For insoluble organics or particles too large to be directly absorbed, the process is more complicated. First, the waste particle is adsorbed by the bacteria. This is a process of adherence where the waste particle becomes attached to the cell wall of the bacteria. The bacteria will then begin to secrete enzymes which act to break down the specific organic. As the organic is broken down, it is then taken into the cell, or absorbed.

The utilization of organic waste as food by bacteria is an accumulative process. Initially, when a complex organic is introduced into a biological system, one type of bacteria attacks one part of the organic material and other bacteria attack the remaining parts. The bacteria digest that portion of the organics they have absorbed through their cell walls and produce certain waste products. These waste products are then used as a food source by other microorganisms which, in turn, produce waste products that are subsequently used as food by yet other microorganisms. This accumulative process continues until the original complex organic is completely broken down and assimilated by the biological population.

3.2.4 Factors Affecting Growth

Several factors affect the growth of microorganisms. These include the following:

1. pH. An environmental factor which influences the growth rate and limits the growth in any biological system is the hydrogen ion concentration, i.e., the acidity or alkalinity of the liquid environment of the process. This is most conveniently expressed as the pH of the system.

   Each species of microorganism is limited by a range of pH values within which growth is possible. The optimum pH value for any species is that at which the growth rate is most rapid. Often this pH range is surprisingly broad. Most bacteria and protozoa have pH optima near 7 but thrive in a range of 5 to 8.

   In biological populations found in waste treatment plants there are a series of individual species of microorganisms acting and interacting at the same time. Within this community species changes can occur as the system responds to changes in the type or quantity of the organic material entering the influent stream. The activities of the species as they feed upon the organic matter and grow results in the formation of acidic or alkaline products. As these products are released from the cell, an increase or decrease in the system pH may occur.

   Each biological system can accept flows within a pH range without upsetting the system or changing the internal system pH. In some systems this range is narrow, but some systems have been known to accept flows with pH variation of 5 to 11 without noticeable effects. pH changes of long duration above or below the acceptable range a system can tolerate are considered toxic. Wide

fluctuations in pH for short periods of time can usually be tolerated by a healthy system.

2. Nutrients. All living cells require a number of basic nutrients for survival. Generally, the two most important for biological systems are nitrogen and phosphorous. These nutrients must exist in certain proportions to maintain a healthy population of microorganisms in the system. Both nitrogen and phosphorous are necessary to maintain cell respiration and reproduction. Nitrogen is needed for generating new cell material while phosphorus is essential to enzyme production. If the amount of these nutrients added is not sufficient the formation of unwanted types of microorganisms is likely to occur.

   Generally, a good rule of thumb for nutrient balance in the incoming wastewater to a biological treatment system is that for each 100 parts of raw BOD_5, there should be about 5 parts of total nitrogen and 1 part of total phosphorus.

3. Temperature. In order to function at maximum efficiency bacteria require a favorable temperature. They are very susceptible to changes in temperature in that their rate of growth and reproduction is definitely affected by such variations.

   As stated earlier, the larger portion of these bacteria thrive best at temperatures from 20°C to 40°C or 68°F to 104°F. These are known as "mesophylic" types. Variations from this temperature range limit the activities of mesophylic bacteria, practically eliminating it at extremely low temperatures and at high temperatures. Temperatures, consequently, are of major importance in the operation of a biological process.

   The optimum temperature is that at which the growth is most rapid, and for most bacteria it is closer to the maximum than to the minimum temperature. Growth at the minimum temperature is typically quite slow. The rate increases exponentially with increasing temperature reaching a maximum at the optimum temperature and falling abruptly to zero at a few degrees above the maximum. For most organisms the growth rate increases two fold for each 10°C rise in temperature between the minimum and optimum.

   Time is an important factor in considering the effects of temperature, particularly temperatures above the range of growth. Some effects of elevated

temperatures are reversible, and short exposure to an elevated temperature may not be lethal although longer exposure at that same temperature would be. The higher the temperature, of course, the less time is required for killing and the greater is the probability that irreversible damage will occur.

When an organism is subjected to a temperature change within the biologically active range, the response of the organism at the new temperature depends on the ability to adapt or acclimate to the new environment. In areas with prominent seasons the temperature changes from winter to summer or summer to winter can cause plant upsets, sometimes of a serious nature.

4. Oxygen Supply. In aerobic biological systems, an adequate oxygen supply is necessary for growth to occur. Oxygen can be introduced to the biological culture through various means depending on the type of systems. Some derive their oxygen supply from the microorganisms themselves, as in the case of algae in ponds. Ventilation, either natural or forced, is required in processes such as activated sludge.

5. Shock. A shock can be defined as any abrupt change in the feed to the system that may result in a process upset. A process shock can be classified as:

   - A qualitative shock - a change in the type of organic substances fed to the organisms;
   - A quantitative shock - a change in the total amount of organic substances fed to the system;
   - A hydraulic shock - a sudden change in flow rates;
   - Toxic shock - this includes such things as pH, temperature, conductivity, toxic materials, etc.
   - Of major concern in a plant is the degree of shock that can be tolerated at any one time without causing process upsets and permit violations. Important points for personnel to realize in handling shock loads are:
   - Biological processes can handle shock loadings up to a certain degree.
   - The degree of shock that can be tolerated by a plant depends upon the stability of the plant at that particular time. (Plants in the process of

recovering from one type of shock are less likely to be able to withstand another shock if this second shock occurs during this recovery period.)

- Complete effects of some shock loads are not immediately visible.
- Temporary rises in flow rates, organic loads or chemical or physical changes (referred to as spikes) do not necessarily constitute shock loads. Equalization capabilities of the plant will dampen the effect of these "spikes" and they often will pass through the process with no adverse effects.

3.2.5 Activated Sludge

One of the most common forms of biological treatment is the activated sludge process. Removal of organic matter from wastewater in the activated sludge process is accomplished by introducing the water to be treated into a tank containing a high concentration of actively growing microorganisms in the presence of dissolved oxygen. The microorganisms use the waste material as a source of food so as to obtain the energy necessary to grow and multiply. In so doing, the microorganisms convert the waste materials into more stable end products such as CO_2, water and more microorganisms. The activated sludge process is illustrated by the basic reaction:

$$\text{Microorganisms} + \text{organic matter} \xrightarrow{O_2} \text{microorganisms} + CO_2 + H_2O$$

As the microorganisms grow and are mixed by the agitators in the aeration basins, or reactor, the individual organisms clump together (flocculate) to form an active mass of organisms called "activated sludge." Wastewater flows into the aeration basins, where oxygen is injected and the activated sludge and the wastewater is thoroughly mixed. This mixture is called "mixed liquor."

Generally, the organisms in an activated sludge culture may be divided into four major classes: floc-forming organisms, saprophytes, predators, and nuisance organisms. These are not distinct groups and in fact, any particular organism may fit into more than one category at a time or may change groups as the selective pressures within the community change.

Floc-forming organisms play a very important role in the process for without them the sludge could not be separated from the treated wastewater. Classification of organisms into the floc-forming group is complicated by the fact that protozoa and fungi

can also cause bacteria to flocculate. Nevertheless, this group is primarily composed of bacteria. Flocculation is thought to be caused by natural polyelectrolytes, although their origin is uncertain.

The saprophytes are the organisms responsible for the degradation of organic matter. These are primarily bacteria and no doubt include most of the bacteria considered to be the floc formers. Nonflocculant bacteria are probably also present but are entrapped within the floc particles formed by the first group. The saprophytes can be subdivided into primary and secondary saprophytes, the primary ones being responsible for the degradation of the original substrates. No doubt the larger the number of substrates the more diverse the community will be because of less competition for the same substrates. The secondary saprophytes feed upon the metabolic products of the primary ones.

The main predators in activated sludge communities are the protozoa which feed upon the bacteria. About 230 species have been reported to occur in activated sludge and they may constitute as much as 5 percent of the mass of biological solids in the system. Ciliates are usually the dominant protozoa both numerically and from biomass estimations. All but one of them are known to feed on bacteria and the most important ones are either attached to or crawl over the surface of sludge flocs. On occasion both amoebae and flagellates may be seen in small numbers but they are not thought to play a major role in good settling, stable communities. It has been suggested that protozoa play a role in the formation of sludge flocs and contribute to the absence of dispersed bacteria in stable communities.

Nuisance organisms are those which interfere with the proper operation of the process when present in sufficient numbers. Most problems arise with respect to sludge settling and are the result of filamentous bacteria and fungi. If only a small percentage by weight of the community is made up of filamentous organisms, the effective specific gravity of the sludge flocs is reduced so much that the sludge is very difficult to separate by gravity settling. This leads to a situation known as bulking.

A properly operated activated sludge process will provide the conditions necessary to encourage the development of the beneficial organisms and to discourage growth of the nuisance organisms.

3.2.5.1 Steps in the Activated Sludge Process

1. Mixing the Activated Sludge with The Incoming Waste. It is very important that the returned activated sludge (RAS) be thoroughly mixed with the incoming waste. The initial mixing is usually accomplished in one of the following ways.

   In a conventional activated sludge process, the RAS and incoming waste are mixed at the inlet to the aeration tank. The agitation provided by the turbulence in the inlet pipes or channels usually provides the initial mixing.

   In a complete mix activated sludge process, the RAS and the incoming waste are mixed in a line or channel and introduced to the aeration tank at various points throughout the length of the tank. Mixing occurs in the line as the liquid travels to its introduction point.

   In a step aeration activated sludge process, the RAS is introduced at the inlet of the aeration tank. The incoming waste is introduced at several points along the length of the aeration tank. Initial mixing occurs within the aeration tank itself.

2. Aeration and Agitation of the Mixed Liquor. Aeration and agitation of the contents of the aeration basins are necessary to further mix the RAS with the incoming waste, keep the sludge in suspension, and supply oxygen required for biological oxidation.

   The degree of mixing within an aeration system exerts a profound effect upon the degree of removal of organic compounds within these aeration basins. The microorganisms are limited in their ability to seek out their food and mixing brings the organic matter into contact with these microorganisms. Good mixing also decreases the chances of localized differences of temperature or nutrient concentrations occurring within the aeration basin.

   If mixing is too vigorous, it is possible that the floc particles that form within these aeration basins can be "sheared" or separated and the settling ability of the sludge in the secondary clarifiers could be impaired. If mixing is not vigorous enough, settling of solids may occur in the aeration basin. Also good contact between the organic matter and the microorganisms will not be accomplished.

   Aeration and agitation of the mixed liquor are generally accomplished through one of two methods: subsurface diffused air or mechanical aeration. In a diffused air system compressed air is introduced at the bottom of the tank. This

causes the contents of the tank to be circulated by the air-lift effect. Two types of diffused air systems are usually found in aeration systems: coarse bubble and fine bubble. Fine bubble diffusers provide for more surface area for air-liquid contact while large bubble diffusers generally present less operational problems such as clogging.

There are several types of mechanical aeration devices. Floating or fixed platform surface aerators are common. Most use blades to agitate the mixed liquor and some utilize an updraft or downdraft pump or turbine. Also in use are submerged turbine aerators and horizontal rotating brush aerators. All these mechanical aeration devices serve to mix the liquid and entrain air bubbles in it.

The basic oxygen requirement is that there shall be sufficient oxygen added to the system to maintain at least 2 ppm of dissolved oxygen in all parts of the system under all loading conditions. The degree of treatment of the influent waste depends on how many microorganisms there are in the aeration system and how well these organisms work. In any activated sludge system, these organisms require an aerobic environment, that is, the presence of dissolved oxygen. As the supply of food (organic matter) to the aeration system is increased, the microorganisms will increase their activities and will demand more oxygen. If the supply of oxygen does not keep pace with the demand, septic or anaerobic conditions may occur.

Extremely high oxygen residuals (9 ppm to 10 ppm) are not beneficial to the system and can sometimes lead to problems. Besides wasting oxygen, such high concentrations of dissolved oxygen can sometimes cause "bubbles" to be carried over into secondary clarifiers and hinder settling in these tanks.

3. Separation of Activated Sludge from the Mixed Liquor. Before the treated waste can be discharged into receiving waters, the activated sludge must first be removed. This is done in secondary or final sedimentation tanks called clarifiers. The cycle of sludge removal from these secondary clarifiers is much more important than with primary tanks. Some sludge is being removed continuously to be used as return sludge in the aeration tanks. This return sludge must be removed before it loses its activity because of the death of aerobic organisms resulting from the lack of oxygen at the bottom of the tank.

It is good practice to operate final clarifiers with a sludge inventory as small as possible. Minimizing sludge may be accomplished by removing solids at the same rate as they are applied. If solids output does not equal input, solids will accumulate in the final settling tank and will eventually spill over the effluent weir. As a result of solids accumulating in secondary clarifiers:

- Solids become thick and difficult to remove from the bottom;
- Portions of the sludge blanket could become anaerobic;
- MLSS concentration of the system will drop;
- Septic sludge gives off gases which could cause sludge to rise.

4. Return of Proper Amount of Activated Sludge. So that the biological solids do not accumulate in the secondary clarifiers they must be removed at an average rate to that at which they are applied. It is necessary to return this sludge as rapidly as possible, with the least amount of water, to the head of the aeration basin. If the return rate is too slow there will be insufficient bacteria in the aeration tank to effectively reduce the organic material. If the rate is too high, settling characteristics of the sludge will be impaired.

5. Wasting of the Excess Activated Sludge. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food such as total organic carbon (TOC) or chemical oxygen demand (COD). It is known that when the microorganisms remove organic matter from the wastewater, the amount of activated sludge increases. It has been estimated that under normal operating conditions about 1/3 of the usable organic matter is used for oxidation while the remaining 2/3 are used for synthesis. Large portions of the incoming waste are inert and not easily used. The result is that much of the substrate removed by the sludge remains in the floc and accumulates as either inert or living solids.

   The objective of sludge wasting is to remove just that amount of microorganisms that grow in a period. When this is done the amount of activated sludge formed by the microorganisms growth is just balanced by that which is removed from the process. This therefore allows the total amount of activated sludge in the process to remain somewhat constant.

This condition is called "steady-state", which is a desirable condition for operation. However, "steady state" can only be approximate because of the variations in the nature and quantity of the food supply and of the microorganism population.

Wasting of the activated sludge can be done on an intermittent or continuous basis. Intermittent wasting has one advantage in that less variation in sludge concentration will occur during the waste period and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling process may be overloaded and that the activated sludge process is out of balance for a period of time.

3.2.5.2 Activated Sludge Flow Models

The two types of flow models referred to in activated sludge treatment are complete mix and plug flow.

1. Complete Mix Flow. In complete mix flow arrangements, the influent waste, mixed with the return sludge, is rapidly distributed throughout the basin and operating characteristics are identical throughout the basin. An important factor in complete mix flow patterns is that the process can handle surges in organic loading without adversely affecting effluent quality.

2. Plug or Series Flow. The plug flow arrangement is the oldest and most widely used form of reactor basin. One of the characteristics of the plug flow configuration is a very high organic loading in the inlet section of the basin. The loading is then reduced as the organic material in the raw wastewater is oxidized. As the complete mix configuration is noted for its ability to assimilate shock loads, plug flow reactors are able to avoid "bleed through," or the passage of untreated materials during peak flows.

3.2.5.3 Factors Affecting the Activated Sludge Process

The factors previously discussed which affect biological processes (pH, temperature, nutrients, oxygen supply, and shock) all apply to the activated sludge process. In addition, several other factors must be considered.

1. Detention Time. It is commonly thought that the removal of organic matter in the activated sludge process takes place in two steps: the removal of organic

matter from the wastewater by the sludge floc and the digestion of the organic material by the microorganisms in the floc.

The sludge floc is formed by mutual coagulation of bacteria with other suspended and colloidal matter. The floc gradually increases to a maximum size. The size depends on how much movement through the water the floc particles can stand without breaking apart (shearing). As the sludge floc moves through the aeration tank, it collides with the suspended and colloidal particles, which then adhere to or adsorb onto the floc. This process is called adsorption. As the floc travels through the basin it will also absorb soluble organic matter, allowing it to pass through the cell wall into the cell. This is called absorption. Adsorbed food matter must be broken into a simple soluble form before it can be absorbed into the cell. The adsorption process occurs very quickly in activated sludge treatment processes, usually requiring only 15 to 30 minutes to occur. But the process of absorption, converting this organic material to carbon dioxide, water and more activated sludge requires a longer period of time. As the microorganisms use the sorbed material the sorptive sites are reopened, allowing more waste material to be trapped by the floc. The process of digesting this organic material must be completed before the organisms leave the aeration system. The aeration tank is sized to provide enough detention time to accomplish the treatment required.

2. Dissolved Oxygen Residual. As previously stated, all aerobic biological processes require an oxygen supply. Proper control of the activated sludge process requires that a residual of at least 2.0 mg/l of dissolved oxygen (DO) is maintained in the aeration basins at all times. Residuals below this point can cause shifts in the predominate species of organisms within the system and may encourage the growth of filaments. Maintaining a DO of 2.0 mg/l is recommended, not because the higher DO levels affect the process in any way, but only because it offers a degree of protection against large increases in organic loadings that may enter the process. Carrying too high a DO level can result in wasted energy (unnecessary cost). The upper limit of DO residuals should be in the range of 5 to 7 mg/l. The secret to control of dissolved oxygen in an aeration system is to carefully monitor all parameters as they enter the aeration system and adjust the DO as needed. As heavy organic loads arrive at the aeration system, the DO residuals should be monitored on an hourly basis as

the change in organic loading takes place. DO residual tests should be run hourly until the change has been completed. As increases in organic loadings take place, it is only necessary to maintain DO levels above 2.0 mg/l at all times. Instantaneous drops in DO residuals to points slightly below 2.0 mg/l at the peak of a change is not a cause for alarm. If the process DO residual recovers immediately (within 2 hours) and holds, no action is required. Consistent drops in DO residual below 1.0 mg/l in a 24 hour period can cause problems and corrective action must be taken.

3.2.5.4 Operational Parameters

There are a number of operating parameters important to the operation of activated sludge process. It must be noted that these operating parameters are provided for reference only. Each individual treatment system will have its own unique operating characteristics.

1. Mixed Liquor Suspended Solids (MLSS). This is a very important measurement and shows the amount of activated sludge inventory. It is recommended that the MLSS be determined on a daily basis.

2. Mixed Liquor Volatile Suspended Solids (MLVSS). This test indirectly shows the active biological fraction of mixed liquor solids and directly tells the amount of inert solids. For example, MLVSS will typically be 70 to 80 percent of the total MLSS. However, during times of heavy infiltration of the sewer system, the carryover of silt into the aeration basins may decrease the MLVSS to 55 to 60 percent. When the percent of MLVSS decreases, the total MLSS must be increased to maintain the same level of active organisms. It is recommended that the MLVSS be determined on a daily basis.

3. Food to Microorganism Ratio (F/M). This parameter is used to express the total loading of organics on the biological system. It is the ratio of pounds of BOD5 entering the aeration basin per day to the pounds of MLVSS in the aeration basin and the secondary clarifier.

   A high F/M reflects a high loading on the activated sludge system which will result in more waste activated sludge generated per pound of BOD removal. A very high F/M (above 0.5) indicates a more unstable system.

A low F/M (less than 0.1) at normal MLSS concentrations indicates a lightly loaded activated sludge plant. The waste sludge should be stable and may not require any added digestion.

F/M ratio is calculated as:

$$\frac{(\text{Aeration Influent BOD, mg/l})(\text{Influent Flow Rate, MGD}) \quad (8.34)}{(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MGD}) \quad (8.34)}$$

4. Sludge Age (MCRT, SRT) is the average length of time the activated sludge solids are in the system. Sludge age is an important parameter, because the amount of time that the microorganisms are given to breakdown the waste products has a significant effect on effluent quality. SA is calculated as:

$$\frac{(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MGD}) \quad (8.34)}{[(\text{Return Sludge VSS,mg/l})\text{x}(\text{Waste Sludge Flow MGD})\text{x } 8.34][(\text{Effluent VSS,mg/l})\text{x}(\text{Effluent Flow, MGD})\text{x } 8.34]}$$

5. Sludge Density Index (SDI). The rate that activated sludge solids settle to the bottom of a final settling tank depends on the settling characteristics of the sludge. These characteristics are determined by a simple settling test, the results of which can be used to determine the SDI. A 1,000 ml sample is collected from the aeration tank and allowed to settle for 30 minutes in a 1,000 ml graduated cylinder. The volume of settled sludge is read at the end of the 30 minutes.

$$\text{SDI} = \frac{\text{MLSS (mg/l)}}{\text{ml of settled sludge after 30 min settling x 10}}$$

A good Sludge Density Index is about 1.0. A sludge with an index of 1.5 is dense and settles quickly. An index of less than 1 means a lighter sludge which settles slowly.

6. Sludge Volume Index (SVI). This index is also used to reflect the settling characteristics of activated sludge, but is defined as:

$$\text{SVI} = \frac{\text{ml of settled sludge after 30 min settling x 1,000}}{\text{MLSS (mg/l)}}$$

In this case, the lower the SVI, the more dense the sludge. An SVI of 100 or less is generally considered a good settling sludge.

7. Microscopic Examination. Microscopic examination of the MLSS can be a significant aid in the evaluation of the activated sludge process. The presence of various microorganisms within the sludge floc can rapidly indicate good or poor treatment. Protozoa play an important role in clarifying the wastewater and act as indicators of the degree of treatment. The protozoa eat the bacteria and help to provide a clear effluent. The presence of rotifers is also an indicator of effluent stability. A predominance of protozoa (ciliates) and rotifers in the MLSS is a sign of good sludge quality. The presence of filamentous organisms and a limited number of protozoa is characteristic of a poor quality activated sludge. This condition is commonly associated with a sludge that settles poorly.

3.2.5.5 Total Solids Inventory Approach

This technique for process control is used by many operators because it is simple to understand and involves a minimum amount of laboratory control. The MLSS control technique usually produces good quality effluent as long as the incoming wastewater characteristics are fairly constant with minimal variations in influent flow and organic loading rates.

With this technique, the operator tries to maintain a constant MLSS concentration in the aeration tank to treat the incoming wastewater organic load. To put it in simple terms, if it is found that a MLSS concentration of 2,000 mg/L produces a good quality effluent, the operator must waste sludge from the process to maintain that concentration. If the MLSS level increases above the desired concentration, more sludge is wasted until the desired level is reached again.

When using the total solids inventory approach for process control the operator should take into account the volume of solids in the aeration tank and in the clarifier, if a significant blanket level is normally maintained.

3.2.5.6 Sludge Age As A Control Parameter

Sludge age, or Mean Cell Residence Time (MCRT) is a process control technique available to the plant operator. Basically, the sludge age expresses the average time that a microorganism will spend in the activated sludge process. The sludge age value should

be selected to provide the best effluent quality. This value should correspond to the loading for which the process is designed. The operator must find the best sludge age for his process by relating it to the organic loading as well as the effluent COD, BOD, and SS concentrations.

This is an important parameter, because the amount of time that the microorganisms are given to break down the waste products has a significant effect on effluent quality. Generally speaking, sufficient time must be permitted for the microorganism to be in contact with the waste to accomplish treatment. If too little time exists, the biological system may have insufficient time to degrade the wastes, resulting in poor quality effluent. If too much time is allowed, the microorganism will deplete the food supply available and begin to die off, resulting in a higher fraction of non-active biological material in the sludge and a resultant loss of "fine" solids in the effluent. Sludge age also directly affects solids settling in the secondary clarifier. A young sludge is generally in a high growth rate phase which results in a dispersed growth biological population characterized by poor settling. An old sludge is characterized by low activity and dense floc which settles rapidly with little filtering action as it settles.

The data required for calculating sludge age is as follows:

- Aeration basin MLSS, mg/L.
- Aeration basin volume, mg.
- RASSS, mg/L.
- Effluent flow, mgd.
- Effluent SS, mg/L.
- WAS flow, mgd.

The determination of the proper target sludge age for the process at any one time is the greatest challenge for the operator. The operator must determine the best sludge retention time for his process by using best judgment in the interpretation of results from other process indicators such as observations of the aeration tanks and clarifiers, as well as final effluent quality. That sludge age which gives the best results will change during the year in relation to external influences such as temperature. Longer sludge ages will

be needed in colder weather when the bacterial culture is less active. At this time you will need more bacteria to do the same amount of work.

The operator should make his changes in sludge age slowly and cautiously and only change the sludge age one day at a time. Personnel should not increase or decrease the wasting rate more than 15 percent from one day to the next. Allow at least three sludge ages to let the process settle down before determining the extent of change in the process that has taken place from a one day's change in sludge age before making any further changes. In other words, it takes three sludge ages for the process to reach a steady state after a one-day change in sludge age.

3.2.5.7 Establishment Of Desirable MLSS Ranges

As stated above, the determination of a desirable sludge age or solids inventory level is based on a number of factors, including organic loading, effluent standards and seasonal variables. Generally, MLSS levels are maintained at lower concentrations in the summer and higher concentrations in the winter.

The lower MLSS levels in the summer months are related to the increased activity of the microorganisms at higher temperatures. During the winter months, the activity of the microorganisms is lower requiring more biomass to treat the incoming waste.

MLSS levels should also take into consideration the organic loading to the treatment plant. Higher organic loadings to the plant will require a higher MLSS level to assimilate the incoming waste. For this reason, food to microorganism ration (F:M) should be calculated for the treatment plant on a regular basis.

3.2.5.8 Monitoring Sludge Blanket Depth

Monitoring the depth of the sludge blanket in the clarifier is the most direct method available for determining the RAS flow rate. The blanket depth should be kept to less than one-fourth of the clarifier sidewall water depth. The operator must check the blanket depth on a routine basis, making adjustments in the RAS to control the blanket depth.

If the depth of the sludge blanket is increasing, an increase in the RAS flow can only solve the problem on a short-term basis. Increases in sludge blanket depth may result from having too much activated sludge in the treatment system, and/or because of a

poorly settling sludge. Long-term corrections must be made that will improve the settling characteristics of the sludge or remove the excess solids from the treatment system. If the sludge is settling poorly due to bulking, the environmental conditions for the microorganisms must be improved. If there is too much activated sludge in the treatment system, the excess sludge must be wasted.

Measurements of the sludge blanket depth in the clarifier should be made at the same time each day (or each shift). The best time to make these measurements is during the period of maximum daily flow, because the clarifier is operating under the highest solids loading rate. The sludge blanket should be measured daily, and adjustments to the RAS rate can be made as necessary. Adjustments in the RAS flow rate should only be needed occasionally if the activated sludge process is operating properly.

An additional advantage of monitoring the sludge blanket depth is that a problem, such as improperly operating sludge collection equipment, will be observed due to irregularities in the blanket depth. A plugged pickup on a clarifier sludge collection system would cause sludge depth to increase in the areas where the improperly operating pickups are located.

3.2.5.9 Sludge Wasting Strategy

Control of an activated sludge process is achieved through the wasting of excess sludge from the system. Success or failure in operating an activated sludge plant depends on proper control of the mass of active organisms in the plant. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food as defined by tests such as chemical oxygen demand (COD) or biochemical oxygen demand (BOD). It is known that when the microorganisms remove BOD from wastewater, the amount of activated sludge increases (microorganisms grow and multiply). The rate at which these microorganisms grow is called the growth rate and is defined as the increase in the amount of activated sludge that takes place in one day. The objective of sludge wasting is to remove just that amount of older microorganisms equal to the new growth. When this is done, the amount of activated sludge formed by the microorganism growth is balanced by that which is removed from the process. This therefore allows the total amount of activated sludge in the process to remain somewhat constant. This condition is called "steady-state" which is a desirable condition for operation. However, "steady-state" can only be approximated because of the variations

in the nature and quantity of the food supply (BOD) and of the microorganism population.

Wasting of the activated sludge is normally accomplished by removing a portion of the RAS flow. An alternate method for wasting sludge is from the mixed liquor in the aeration tank. There is a much higher concentration of suspended matter in the RAS than there is in the mixed liquor. Therefore, when wasting is practiced from the mixed liquor, larger sludge handling facilities are required. Wasting from the RAS takes advantage of the gravity settling and thickening of the sludge that occurs in the secondary clarifier. However, wasting from the mixed liquor has the advantage of not wasting excessive amounts of sludge because of the large quantity of sludge involved.

Wasting of the activated sludge can be done on an intermittent or continuous basis. The intermittent wasting of sludge means that wasting is conducted on a batch basis from day to day.

Intermittent wasting of sludge has the advantage that less variation in the waste sludge concentration will occur during the wasting period, and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling facilities in the treatment plant may be loaded at a higher hydraulic loading rate and that the activated sludge process is out of balance for a period of time until the microorganisms regrow to replace those wasted over the shorter period of time.

It is the objective of process control to approach a particular "steady state" in the activated sludge system. Proper control of the WAS will help provide this steady state while producing a high quality effluent with minimum operational difficulties.

3.2.5.10 Oxygen (DO) Uptake Rate

A simple, but valuable, test the operator can use to monitor the status of the plant is the DO uptake rate test. This is a quick and easy procedure that allows the plant operator to assess the activity of the microorganisms in his biological system. By measuring the rate at which DO is used in a sample of mixed liquor collected from the aeration basin and comparing the results with normal readings for the plant, the operator can determine if the microorganisms are more active than usual or if they are being inhibited.

The plant operator should measure the DO uptake rate in the aeration basin each day so that a "typical" uptake rate for the treatment plant can be identified. This normal value should be established based on readings taken during times when the plant is operating efficiently. An uptake rate lower than normal would indicate low activity, and a high rate would indicate high activity. A low uptake rate in the aeration basin is an indication of impending problems. Lower than normal influent BOD loadings, too low or high a pH, low DO levels, or the presence of toxic material will cause low DO uptake rates. A high oxygen uptake rate indicates higher BOD loadings to the plant than usual. The DO uptake test can be used as a tool to alert the operator of impending problems and give him time to make the necessary adjustments before the performance of the plant is adversely affected.

3.2.5.11 Oxygen Uptake Rate Determination

A. General

This test measures the rate at which activated sludge organisms use available oxygen.

B. Apparatus

1. DO meter with membrane probe.
2. BOD bottles.
3. Stopwatch or timepiece.
4. Magnetic stirrer and stir bars.
5. Necessary assorted glassware.

C. Procedure

1. Calibrate meter according to manufacturers instructions.
2. Shake freshly collected sample vigorously in bottle with air space to increase the DO concentration.
3. Place a stir bar into the bottom of a BOD bottle. Pour sample to overflowing in bottle. Insert DO probe and place bottle on magnetic stirrer with vigorous stirring.

4. When DO reading stabilizes, read and record initial DO and start timer. Record DO readings at intervals of 1 minute. Read and record DO for 15 minutes or until DO drops to 1.0 mg/L DO.

D. Calculations

$$\text{Oxygen Uptake Rate (OUR)} = \frac{\text{DO initial - DO final}}{\text{time interval}} \times 60 \text{ (min/hr)}$$

3.2.5.12 Settleability Tests

One of the best process monitoring tools available to the operator is the 30-minute settling test. This test is valuable because it not only helps the operator determine if his plant is running efficiently, but, if problems do exist, it also can help him locate the source of those problems. This is extremely important and time-saving to the operator because once he knows the problem source, he can concentrate his efforts on conducting tests and investigating probable problem causes which are specific to that area of the plant.

For instance, if during the 30-minute settling test the MLSS settle well in the 2-liter settleometer, but are not settling well in the clarifier, then the problem is probably in the clarifier. Poor settling in the clarifier could be caused by too high a sludge blanket, denitrification, equipment malfunction, etc. On the other hand, if the MLSS do not settle well in the 30-minute settling test, then you wouldn't expect them to settle well in the clarifier, and the problem area is probably the aeration basin. Some typical problems specific to the aeration basin include high DO levels, nitrogen or phosphorous deficiency, low pH, low DO, improper F/M ratio, high BOD loadings, etc. The 30-minute settling test is a reasonable approximation of what is happening in the secondary clarifiers. Through careful observation of the settling rate and sludge quality, the operator can identify problems which may be occurring in the system. Among the types of final clarifier settling problems the 30-minute settling test can help identify are:

Type	Symptoms	Cause
Sludge Bulking	Large floc distributed throughout the clarifier; poor compaction in sludge blanket; microexam indicates predominance of filamentous organisms	Organic overloading, incorrect F/M ratio, nutrient (N)(P) deficiency
Sludge Rising	Biological solids refloat to the clarifier surface after settling to the bottom	Too long sludge detention time in clarifier, resulting in gas formation due to septicity and/or denitrification
Deflocculation	Small, buoyant floc; turbid supernatant	Toxicity, nutrients deficiency, organic shock loads, anaerobic conditions
Straggler Floc	Small, light floc; clear supernatant	Low sludge age
Pin Floc	Small, dense floc, turbid effluent, rapid settling floc	High sludge age

3.3 SECONDARY CLARIFICATION

3.3.1 Introduction

Clarification refers to any of several treatment processes which are used to remove suspended solids particles from the wastewater. The removal of suspended solids can be important for at least three reasons. First, most treated wastewater discharges are permitted with strict limits on the amount of suspended solids that the effluent can contain, so as to reduce the environmental impact of these solids (such as excess siltation in receiving streams). Second, many of the suspended solids in wastewater are organic in nature, and will cause a higher oxygen demand (biochemical or chemical) in the effluent or subsequent treatment processes unless they are removed. And third, the presence of large amounts of suspended solids can cause problems in downstream treatment processes, including the sedimentation and accumulation of solids in tanks, channels, or pipelines.

For these reasons, gravity clarifiers are often used at the beginning, end, and sometimes even the middle of process trains for wastewater treatment. These solids removal units are sometimes referred to as primary, secondary, tertiary, or final clarifiers, depending on their location and function in the treatment system. Basically, the purpose and operation of each of these units is the same, although the settling characteristics of the solids to be removed are often quite different. Since the settling characteristics of solids particles will vary with the wastewater and the treatment system, the operation of a clarification unit should be based on an understanding of the theory of the gravity clarifiers and the variables which affect their efficiency. The Howard AFB WVVTP utilizes secondary clarifiers.

3.3.2 Theory of Operation

Most of the suspended solids particles present in wastewater have a density that is either greater or less than that of water. As a result, these solids will tend to either sink or float under quiescent (still) conditions. It is for this reason that wastewater collection and treatment systems are designed to insure a turbulent flow of wastewater that will keep these solids particles in suspension until they reach an appropriate solids removal process, such as a grit chamber or gravity clarifier. A gravity clarifier is simply a large volume tank that is designed for efficient solids removal. It includes a system for the withdrawal of settled or floating solids, and it often has baffles and weirs to insure that quiescent conditions exist and to minimize any short-circuiting that would reduce solids

removal efficiency. Clarifiers are designed to remove a large portion of those particles that have been allowed to pass through grit chambers.

For purposes of discussion, clarifiers are said to have four zones: inlet, clarification, sludge and outlet. The liquid to be clarified is admitted to the tank through the inlet zone. Separation of the solids from the liquid takes place in the relatively quiescent clarification zone. The clarified effluent is then removed through the outlet zone. Separated solids are allowed to accumulate, compact and are then withdrawn from the sludge zone.

As previously mentioned, suspended solids are removed in a gravity clarifier by virtue of the difference between their density and that of the surrounding wastewater. Density simply refers to the weight of an object or a material that has a known volume. For example, the density of pure water at 60°F is approximately 62.4 pounds/cubic foot. Sometimes density is expressed using another term, called specific gravity. The specific gravity of a material is equivalent to its weight divided by the weight of an identical volume of pure water. Pure water has a specific gravity of 1.0 by definition. Therefore, an object that has a density of 124.8 pounds/cubic foot (twice that of pure water) would have a specific gravity of 2.0. Regardless of how it is expressed, any object with a specific gravity (or density) greater than water will tend to sink, while an object that is less dense than water (specific gravity less than 1.0) will tend to float. And, of course, a particle that has the same density as water (that is, it weighs the same amount as the water it displaces) will neither sink nor float.

The rate at which solids particles settle (or float) depends on the amount of difference between their density and that of the wastewater. Particles that have a density much greater than water will settle more rapidly than those with a density only slightly greater than water. Likewise, a particle that is slightly less dense than water will rise more slowly than a particle that is much less dense than water. This is an important consideration, since many of the settleable suspended solids particles typically found in wastewater treatment plants are only slightly more dense than water. The specific gravity of these particles is often within the range of 1.00 to 1.05. At the same time, there may also be solids present that have specific gravities much greater than water (in the range of 1.1 to 2.0) which will rapidly settle out and accumulate in process tankage and piping upstream of clarification, unless turbulent flow conditions are maintained.

Two other factors affect the rate of solids settling (or floating). These are (1) particle size, or mass, and (2) particle shape. In general, a larger particle (that is, one having a greater mass) will sink or rise faster than a smaller particle having the same density. Some particles, called colloids, are in fact so small that they cannot be separated from water using gravity alone and must first undergo coagulation and flocculation to increase their size so that they can be removed in a gravity clarifier.

In addition to particle size, the shape of a particle is also important. A particle that is perfectly spherical in shape will settle faster than a particle made of the same material and having the same mass (total weight) that is more irregularly shaped. The reason for this is that there is more drag or friction created by irregularly shaped particles as they settle through water, which tends to slow descent. As an example of this, imagine two identical pieces of paper that are dropped to the floor. Both pieces will fall in about the same amount of time. However, if one piece of paper is tightly wadded up and the other is lightly crumpled, the tightly wadded piece will fall faster than the lightly crumpled piece, even though they have the exact same mass and density. The reason for this is that the lightly crumpled piece of paper is subject to more friction or drag when falling through the air, which makes it fall more slowly.

To summarize, suspended solids particles can be separated from wastewater under the force of gravity by virtue of the difference between their densities and that of the wastewater. The rate at which these particles settle (or rise) depends on the magnitude of this density difference as well as upon the size (mass) and the shape of the solids particles. Therefore, any factors which change the relative densities of the suspended solids particles and the wastewater, or any factors which change the size or shape of the solids particles, will affect the rate of solids settling during gravity clarification. The settling rate (expressed in terms such as feet per hour) is important since it determines how well the clarifier will perform. It shows what fraction of the influent suspended solids will be captured and removed.

A factor which greatly affects settling rate is hydraulic residence time. Imagine a solids particle that settles at a rate of 10 feet per hour under quiescent conditions. If this particle were placed into a tank of water near the surface, it would settle at a constant rate of 1 foot every 6 minutes (10 feet/hour) until it reached the bottom of the tank. If the

tank contained 10 feet of water, this would take 1 hour or less, depending on the original depth at which the solids particle was placed into the tank.

Now imagine the same particle being placed into one end of a 200-foot long tank in which water is flowing horizontally at a constant rate of 2 feet per minute. (For this discussion, we will ignore effects of the inlets and outlets to the tank and assume that the flow is perfectly distributed from top to bottom and that it travels only horizontally). At this flow rate, we can assume that the water in the tank is not turbulent enough to keep the particle in suspension and that the particle will still settle at a rate of 10 feet/hour. What occurs is illustrated in Figure 3.1. It will take 100 minutes (200 feet divided by 2.() feet/minute) for the water to travel through the tank. If, during its diagonal course of travel, the particle settles vertically toward the bottom of the tank at a rate of 1.0 foot in 6 minutes, it will rest on the floor of the tank in 60 minutes if the tank is 10 feet deep. In other words, if the particle settles at the rate of 10 feet in 60 minutes, it should settle in the first 120 feet of the tank.

Now consider that the horizontal flow rate is doubled to 4.0 feet per minute, as shown in Figure 3.1b. In this case, it will only take 50 minutes for the water to pass through the tank. If the same particle enters the tank at the water surface, it will not have time to settle to the bottom of the tank before it reaches the other end, because its vertical settling velocity is only 10 feet per 60 minutes and the tank is 10 feet deep.

From the previous discussions, it should have been obvious that hydraulic residence time (HRT) has an important effect on whether a particle with a given settling rate will be captured or not. In general, with a longer residence time, more of the slower settling particles will settle out.

3.3.3 Density Currents

Short-circuiting can occur in settling basins if the incoming flow has a higher temperature or density than the mass of liquid in the basin. This condition is usually evidenced by violent rolling of masses of liquid with entrained solids to the surface. Short-circuiting can occur when the temperature suddenly increases 1 to 2°F with light flocculant-type solids.

Figure 3.1

If the incoming flow is colder than the water in the basin, it can flow along the bottom at a high velocity and reduce the efficiency of solids removal.

3.3.4 Operating Parameters

There are a number of operating parameters important to the efficient operation of clarifiers.

3.3.4.1 Hydraulic Loading

Hydraulic loading on a clarifier is generally measured in terms of surface loading rate. Surface loading rate is defined as the average influent flow (gallons per day) divided by the surface area of the clarifier. It is a measure of the upward velocity of flow and must be kept low enough to prevent flow of sludge over the weirs. Surface loading rate is calculated as:

$$\text{Surface Loading Rate, GPD / ft2} = \frac{\text{Influent Flow Rate, GPD}}{(\text{Clarifier Surface Area, ft2})}$$

Secondary clarifiers will operate efficiently when the loading rate is in the range of 400-800 gpd/ft^2.

3.3.4.2 Detention Time

Detention time is defined as the average time a particle of water is in the clarifier. Detention time is calculated as:

$$\text{Detention Time, hrs} \dagger \frac{\text{Clarifier Volume, Gal)(24Hrs / Day)}}{\text{Influent Flow Rate, GPD}}$$

Secondary clarifiers will operate efficiently when the detention time is between 1.5 and 2.5 hours. If detention time is too short a smaller portion of the suspended solids will settle, and removal efficiency will decline. If detention time is too long removal efficiency will not improve materially and can lead to wastewater becoming septic in the clarifier.

3.3.4.3 Weir Overflow Rate

Weir overflow rate is defined as the average influent flow (gal/day) divided by the weir length. It should be kept low enough to provide quiescent conditions in the clarifier.

Weir overflow rate is calculated as:

$$\text{Weir Overflow Rate, GPD / ft} = \frac{\text{Influent Rate, GPD}}{\text{(Weir Length of Clarifier, ft)}}$$

Weir loadings of secondary clarifiers will generally be around 10,000 GPD per linear foot.

3.3.4.4 Solids Removal

Solids must be removed from clarification tanks or, eventually, the settled sludge level will increase to the point that solids are washed out with the tank's effluent. Solids may be removed continuously or in a batch method. Solids which settle in secondary clarifiers are sometimes removed continuously and sometimes in batches depending on the plant size and type of treatment process.

3.4 SLUDGE STABILIZATION

3.4.1 Introduction

Sludge stabilization processes are key to the reliable operation and performance of any wastewater plant. It is not inappropriate to think of a wastewater plant as a sludge factory. In a sludge stabilization process several factors must be considered, including quantity of sludge to be treated, and ultimate disposal of the sludge.

Sludge stabilization is basically a process to either reduce volatile solids, significantly reduce pathogens, or prepare the sludge for further processing.

3.4.2 Aerobic Sludge Digestion

Sludge stabilization processes are key to the reliable performance of any wastewater treatment plant. Handling sludge produced as a by-product of wastewater treatment operations is often a technical challenge.

The stabilization of wastewater treatment plant sludges during the aerobic digestion process can be defined as the destruction of degradable organic components of the sludges by aerobic, biological mechanisms. The aerobic digestion process represents a continuation of the suspended growth biological treatment process and is based on theoretical concepts similar to those of the activated sludge process.

The objectives of the aerobic digestion process include production of a stable end product by oxidizing sludge organisms and other biodegradable organics, reduction of the sludge mass and volume, and conditioning of the sludge for further processing. Basically, the process involves the aeration of waste solids in the absence of additional nutrients for extended periods of time. In the absence of an external source of nutrients, endogenous respiration occurs with a subsequent decrease in volatile suspended solids.

During the digestion process, cell tissue is oxidized aerobically to carbon dioxide, water and ammonia or nitrates. Because the aerobic oxidation process is exothermic, a net release of heat occurs during the process. Although the digestion process should theoretically go to completion, in actuality only about 75 to 80% of the cell tissue is oxidized. The remaining 20 to 25% is composed of inert components and organic compounds that are not biodegradable. The material that remains after the full completion of the digestion process exists at such a low energy state that it is essentially biologically stable. Consequently it is suitable for a variety of final disposal options.

One of the advantages of the aerobic digestion process is its relative simple operation. As long as the biological environment (temperature, pH, absence of toxic substances, etc.) is maintained suitable to support life, the aerobic digestion process is essentially self-sustaining.

The primary disadvantage commonly attributed to the aerobic digestion process is the higher power cost associated with oxygen transfer. Recent developments in the aerobic digestion process, such as highly efficient oxygen transfer equipment, and research into operation at elevated temperatures, may reduce this concern. Other disadvantages frequently cited include the reduced efficiency of the process during cold weather and the mixed results achieved during mechanical dewatering of aerobically digested sludges.

3.4.2.1 Operation

Aerobic digesters can be operated in batch or continuous mode. The supernatant obtained after solids separation is normally discharged back to the treatment plant. While the quality and quantity of this supernatant on the treatment plant must be evaluated, the characteristics of the supernatant are relatively innocuous.

Foaming problems are common in aerobic systems, especially in systems using surface aeration devices. Foaming problems are generally caused by high organic loading rates during summer periods. Growth of filamentous bacteria can also cause foaming problems. Foaming may also occur in the spring and fall while the microorganisms reacclimate to summer or winter temperatures.

3.4.2.2 Dewatering

The dewatering characteristics of digested sludge decreases as the sludge age increases. Optimal dewaterability seems to occur after 1 to 5 days of aeration.

The dewaterability is also affected by the degree of mixing provided during the digestion process. High degrees of mixing will break the biological floc, thereby reducing the dewaterability.

3.5 SLUDGE DEWATERING

3.5.1 Introduction

Sludge is a major by-product of domestic wastewater treatment. Its disposal is a problem comparable in importance and magnitude to the liquid wastewater treatment problem. Sludge dewatering is an economic necessity to reduce the sludge volume requiring disposal and to retard biological decomposition.

The objective of sludge dewatering is to reduce the capital and operating costs associated with its ultimate disposal by substantially reducing the sludge volume. Dewatering a sludge from 5 percent to 25 percent solids concentration reduces the sludge volume to approximately one-fifth (20 percent) of its original volume.

The sludge dewatering concept is embodied within a category of processes designed to extract water from sludge. In dewatering systems, sufficient water is extracted from the sludge so that it assumes a nonfluid character. No longer a liquid, dewatered sludge is characterized as a damp solid. An arbitrary index used in the wastewater industry to distinguish between dewatered sludge and thickened sludge is a minimum 15 percent solids content for dewatered sludge. It is important to note, however, that the physical characteristics displayed by sludges of a given moisture content will vary, depending on sludge type and conditioning.

Sludge dewatering may be accomplished by a number of natural and mechanical means that incorporate the use of gravity, evaporation, vacuum, centrifugal force, pressure, capillary action, or a combination of any of the above.

Prime considerations in the selection of sludge dewatering methods are cost, availability of disposal site, aesthetic factors, and the environmental impact of the disposal approach on people.

3.5.2 Sludge Drying Beds

Despite a variety of mechanical methods available for sludge dewatering, approximately two-thirds of treatment plants in the United States have sludge-drying beds such as those utilized at the Howard WWTP. By using this procedure a sludge can be dried to about a 75 percent or less moisture content in a few weeks of dry weather. Such a sludge is conveniently handled with a shovel or garden fork. The area required for sludge drying beds is primarily determined by climatic conditions.

The dewatering of the sludge on sand beds occurs by filtration of the water through the sand and evaporation of the water from the sludge surface. Filtration is usually accomplished on digested sludge in 1 to 2 days. This is dependent upon the characteristics of the sludge and the depth to which the sludge is placed on the bed. After most of the water is filtered off, the sludge then dries to an equilibrium moisture content with the surrounding air. This final moisture content depends upon the temperature and relative humidity of the air and the nature of the water content. Bound water retained in capillaries and in cell walls will result in a high final moisture content. A high bound-water content is representative of raw or partially digested sludge. Well-digested sludge possesses a low bound-water content and is easily dewatered on sand beds.

Sludge-drying beds normally consist of 4 to 6 inches of sand over 8 to 12 inches of gravel or stone. The bed is drained by tile underdrains placed in the gravel about 6 to 12 feet apart. The spacing of the underdrains depends on the drainage characteristics of the subsoil. The underdrainage may be returned to the head of the plant. The side walls of the beds are generally made of concrete. The side walls are normally about 12 inches high and the beds are filled to a depth of 8 to 10 inches. Several smaller beds serve the purpose better than one large bed. The width of the drying bed is so chosen that the vehicle used for removing the dried sludge can be loaded conveniently. Common values for width are about 20 feet. The length is generally held below 100 feet. Sludge may be expected to flow approximately 100 feet from a single outlet when the bed slope away from the outlet is about 0.5 percent.

3.6 DISINFECTION

3.6.1 Introduction

From the viewpoint of health, the disinfection process is a very important consideration. It is the unit process that provides a barrier to the transmission of waterborne disease by destruction of pathogens before release of the waste stream to the environment. Disinfection of wastewater effluents has contributed to the dramatic reduction that has occurred through the years in the incidence of waterborne disease out-breaks. Disinfection refers to the selective destruction of disease-causing organisms. All of the organisms are not destroyed in the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.

3.6.2 Liquid-Gas Chlorine

Chlorine is one of the chemical elements. Commercial chlorine is a liquified gas under pressure. As a liquid, it has a clear, amber color. In a gaseous form, it has a greenish-yellow color and a strong pungent odor. Chlorine is fed as a gas from 150-pound bottles at the Howard AFB WWTP. Liquid chlorine is about one and one half times as heavy as water and as a gas it is heavier than air. Chlorine is neither explosive nor flammable; however, it will support combustion. At atmospheric pressure, liquid chlorine boils at about -30°F and freezes at about -150°F. One volume of liquid chlorine, when vaporized, will yield about 460 volumes of gas. When exposed to normal atmospheric pressure and temperature liquid chlorine will vaporize to a gas.

Chlorine has a very strong affinity for many substances and will react with almost all the elements, and with many inorganic and organic compounds, usually with the evolution of heat. At elevated temperatures, it reacts vigorously with most metals. In a moisture-free state at ordinary temperatures it is relatively non-corrosive. However, in the presence of moisture it is highly corrosive.

Several reactions will occur simultaneously when chlorine is added to clear wastewater. The reactions are affected by temperature, pH, buffering capacity of the wastewater and the nature of the chlorinating agent.

When chlorine is added to water the chemical reaction is:

$$Cl_2 + H_2O = HOCL + HCl$$

$$HOCl = H^+ + OCl^-$$

At pH values below 7.5, the hypochlorous acid (HOCl) is the predominant compound, while at pH values above 7.5, the hypochlorite ion (OCl^-) predominates. Hypochlorous acid is the more effective disinfection agent. The HOCl and OCl^- available after all reactions have been completed are defined as free chlorine residual.

Wastewater contains many complex substances which will react directly with chlorine. Any ammonia available will react with the HOCl to form chloramines. Chloramines are also disinfecting agents, although not as effective as free chlorine. The chloramine residual is called combined residual.

Before the chlorine and the chloramines can destroy the bacteria, all other direct chemical reactions must be satisfied. The chlorine demand of the wastewater is the amount of chlorine needed to satisfy direct chemical reactions and to produce a minimum residual of chlorine or chloramine.

3.6.2.1 Mixing

It is imperative that the chlorine solution and wastewater be mixed as instantaneously and completely as is mechanically possible. This rapid mixing is termed flash mixing and is necessary to assure that chlorine is available to react simultaneously with every chemically active soluble and particulate component of the wastewater.

In the design of the chlorination system, it is important to provide conditions that will limit the release of chlorine or chlorine compounds from solution. This is necessary from an efficiency standpoint and to prevent a health hazard from chlorine gas in the atmosphere. The most essential conditions are (1) that the chlorine distributor should be submerged at least 2 ft below the wastewater level when chlorine water solution is applied and from 5 to 10 ft, depending on amount fed, when chlorine gas is applied with effective diffusion, and (2) that the wastewater flow following the application and adequate mixing of chlorine should not be subjected to excessive turbulence.

3.6.2.2 Contact Time

Once chlorine is completely mixed with wastewater, plug flow through the contacting system must be maintained. The more closely a contactor design approaches 100 percent plug flow, the better the performance should be.

Plug flow contacting can be effectively accomplished by proper utilization of outfall lines that should always flow full. Successful contacting can also be provided in open channels, although the rectangular and other compact designs provide more economical use of land in most locations. All contactors should be designed with flow gradients that minimize settling of solids. although some solids accumulation is unavoidable. Solids and any slime accumulations on fluid contact surfaces must be removed at regular intervals. Carelessness in this regard can lead to increased chlorine demand and erratic bacterial quality in the disinfected effluent.

Assuming 95 percent plug flow, a minimum contact time of 30 minutes at maximum design flow is a good guideline for general use. A nominal increase in contact time (under the flow conditions specified) may be advantageous in some situations, but a reduction in the contact time will reduce the margin of safety unless an offsetting increased chlorine concentration is provided.

3.6.2.3 Dosage and Residual Control

Successful disinfection with chlorine is extremely dependent on providing rapid response to fluctuating chlorine demand to maintain the chlorine residual at a predetermined desirable level.

Effective disinfection thus requires that there be a defined chlorine residual after a suitable contact period. Because the waste of each community requires a special determination of the dosage that will yield the desired or required chlorine residual, efficient and economical operation demands that the application rate be regulated as often as necessary to insure efficient and economical operation. Only by frequent determinations of chlorine residual can the dosage rate, and thus the effectiveness of disinfection, be satisfactorily controlled. Satisfactory disinfection of secondary wastewater effluents generally can be obtained when the chlorine residuals after 15 to 30 minutes contact are between 0.2 and 1.0 mg/L. A residual of 0.5 mg/L after 15 minutes contact appears to be a reasonable average.

Chlorine residual is the critical factor in disinfection. The chlorine applied must persist long enough to attain the desired coliform reduction. Others factors which are involved in the chlorine disinfection process include pH, temperature, concentration of organisms, and the nature and size of particulate material present.

3.7 ADDITIONAL REFERENCES

To enhance the operator's knowledge of the treatment processes at the Howard AFB wastewater plant, a number of additional references are available. These include:

- Sacramento Course - *Operation of Wastewater Treatment Plants*, Volumes 1 and 2
- Sacramento Course - *Industrial Waste Treatment*
- Air Force Manual AFM 91-32 - *Operation and Maintenance of Domestic and Industrial Wastewater Systems*
- Standard Methods for the Examination of Water and Wastewater, 18th Edition
- Manual of Practice OM-9 - Operation and Maintenance of Activated Sludge Plants
- Manual of Practice 7 - Operation and Maintenance of Wastewater Collection Systems
- Manual of Practice OM-3 - Plant Maintenance Program
- Manual of Practice 11 - Operation of Wastewater Treatment Plants
- Manual of Practice OM-1 - Wastewater Sampling for Process and Quality Control

All of the above manuals of practice (MOP) are available from the Water Environment Federation.

CHAPTER 4
SAMPLING AND ANALYTICAL SCHEDULE

CHAPTER 4
SAMPLING AND ANALYTICAL SCHEDULE

4.1 INTRODUCTION

The purpose of the analyses performed in the Howard AFB WWTP laboratory is to provide data to be used in decision making and fulfill requirements of the Overseas Environmental Baseline Guidance Document. By relating lab results to the waste treatment operation the operator can effectively make process decisions, determine the efficiency of the treatment process, identify trends in the process and determine the causes of plant upsets.

The value of any laboratory result depends on the integrity of the sample. Too often, the sole burden for providing accurate laboratory results rests on the analyst running the sample. However, the method used in obtaining the sample is just as important to the analyst as the analytical procedures he or she follows.

Obtaining a sample for laboratory analysis is based on the assumption that the sample obtained is a part of the whole being measured. This idea is most important because if the sample is not truly representative, all subsequent conclusions, decisions and actions will be affected by the errors in the sample. Samples must be collected so that nothing is added or lost, and that no changes occur during the time between collection and laboratory examination of the sample. Since the design and successful operation of any wastewater treatment plant are dependent upon the results of laboratory analysis, sampling is one of the most critical steps and the one typically introducing the greatest errors in these results. Baseline Guidance Document Criteria samples and other recommended process control samples for the Howard AFB wastewater plant are presented in Table 4.1. The laboratory location where analyses are to be performed is also presented in Table 4.1.

TABLE 4.1

**HOWARD AFB WASTEWATER TREATMENT PLANT
SAMPLING SCHEDULE**

Parameter	Frequency	Laboratory	Guidance Document Requirement
Influent BOD	2/week	WWTP	Yes
Secondary Effluent BOD	2/week	WWTP	
Final Effluent BOD	2/week	WWTP	Yes
Stream Above (0.5 miles) BOD	1/week	WWTP	
Stream Below (1.0 miles) BOD	1/week	WWTP	
Stream Below (1.5 miles) BOD	1/week	WWTP	
Influent TSS	Daily	WWTP	
Secondary Effluent TSS	Daily	WWTP	
Final Effluent TSS	Daily	WWTP	
Aeration Tanks TSS	Daily	WWTP	
Aeration Tanks VSS	Daily	WWTP	
Return Sludge TSS	Daily	WWTP	
Return Sludge VSS	Daily	WWTP	
Secondary Effluent VSS	Daily	WWTP	
Final Effluent VSS	Daily	WWTP	
Aeration Basins Settleable Solids	Daily	WWTP	
Return Sludge Settleable Solids	Daily	WWTP	
Final Effluent Setteable Solids	Daily	WWTP	Yes
Effluent Dissolved Oxygen (D.O.)	Daily	WWTP	
Stream Above (0.5 miles) (D.O.)	1/week	WWTP	
Stream Below (1.0 miles) D.O.	1/week	WWTP	
Stream Below (1.5 miles) D.O.	1/week	WWTP	
Aeration Tank D.O.	Daily	WWTP	
Influent pH	Daily	WWTP	
Effluent pH	Daily	WWTP	Yes
Influent Temperature	Daily	WWTP	
Effluent Chlorine Residual	Daily	WWTP	
Digester Total Solids	2/week	WWTP	
Digester Volatile Solids	2/week	WWTP	
Effluent Fecal Coliform Bacteria	Daily	WWTP	*

* Fecal Coliform is not a Overseas Environmental Baseline Guidance Document requirement but was strongly recommended as the result of an ECAMP inspection.

The validity of the laboratory analysis will depend upon attention to the following details:

1. Be sure that the sample and sampling point will be truly representative of the wastewater.
2. Use proper and acceptable sampling techniques.
3. Be sure that proper sample preservation techniques are followed until the samples are analyzed.

4.2 SAMPLING TECHNIQUES AND CONSIDERATIONS

Because of the lack of uniformity of wastewater, attention to the following basic principles will aid in obtaining a proper sample:

1. Sampling points must be selected carefully to assure good mixing of the material to be sampled. Samples should be collected from the main body of flow where the velocity is high and will not be influenced by previous deposits or interfering side currents.
2. Sampling points should be well marked so that all samples are taken from the same place. In addition, proper sampling equipment should be available and adequate safety precautions must be observed.
3. Sampling containers should be rinsed two or three times with the water to be collected before sample collection except when biological samples are to be collected or when the sample bottle contains a chemical preservative.
4. Sample lines should be well flushed before sample collection to ensure that the sample is representative of the supply source. If, for example, a sample line will hold a volume of 3 gallons from supply source to sample tap, then a minimum of 5 gallons of wastewater should be drained from the line before the sample is obtained.
5. Appropriate container for the type of analysis to be run should be used (see Table 4.2).
6. Proper sample preservation techniques should be used (see Table 4.2).
7. Adequate volume of sample must be obtained. Samples should be large enough for the required analysis plus an additional amount for a second confirmation analysis in case of doubtful results (see Table 4.2).
8. Sample containers should be labeled as to date, time, exact sample point, type of sample (grab or composite), sample collector, preservatives, if any, and any other information that might have influence on the methods of analysis, results, or interpretation of those results.
9. Composite sample reservoirs should be well-mixed before samples are obtained from them, and all samples should be mixed again before analysis.

10. The appropriate sample type (grab or composite) must be obtained depending on the type of analysis to be run. Reference Table 4.4.

11. Samples should be analyzed as soon after collection as possible for greatest reliability. Some tests must be run on site because the sample composition will change before the sample reaches the lab.

12. Sampling times for grab samples should be selected to represent typical weekday averages or varied from day to day to represent a cross-section of the waste characteristics. Remember, a sample taken early Monday morning may, in actuality, be a sample of the waste from Sunday night.

13. Where necessary to avoid an excess of floating material, the mouth of the collecting container should be held a few inches below the surface level.

4.2.1 Grab Samples

Grab samples are representative of the characteristics of the wastewater at the instant the sample is caught. When it is only possible to collect grab samples it is preferable that they be collected when the treatment plant is operating at peak flow or organic load conditions. Grab sampling times may be staggered to account for the hydraulic detention time of each unit. If the hydraulic detention time of a process unit is 2 hours, the grab sample of the effluent may be collected 2 hours after the influent sample, thus the samples can be assumed to be representative of the wastewater before and after treatment.

In addition, a grab sample may be taken for any of the following reasons:

1. The waste stream to be measured does not flow on a continuous basis.
2. A "slug" or batch discharge or other unusual or undesirable situation is observed.
3. A condition or operation is of short duration and quite uniform.
4. The waste characteristics are relatively constant over extended periods of time.
5. To determine if a composite sample is averaging out extreme changes in a parameter (i.e., pH) that can be detrimental to the treatment process.
6. Permit requirements dictate grab samples for analyses of selected parameters.

4.2.2 Composite Samples

A composite sample results from the combination of multiple grab samples on a time or flow proportionate basis over a set time period. The composite sample is useful for analysis of wastewater constituents that do not deteriorate or change over extended time periods with proper preservation, and where the average composition of the wastewater is sought. Composite samples provide useful data if the fluctuations in wastewater characteristics are not extreme and tend to minimize the effect of intermittent changes in wastewater characteristics and flow. Currently, samples are manually collected and composited according to flow at the Howard WWTP. Samples are collected every two hours during periods when the WWTP is staffed.

The best type of composite sample is one in which the volume of each grab sample is in direct proportion to the flow reading at that instant. The following example illustrates the sample volumes to be collected on a 12-hour composite:

Time	Flow (MGD)	Factor	Sample Volume(ml)	Time	Flow (MGD)	Factor	Sample Volume (ml)
6am	0.2	100	20	12N	1.4	100	140
7am	0.3	100	30	1pm	1.6	100	160
8am	0.6	100	60	2pm	1.5	100	150
9am	0.9	100	90	3pm	1.3	100	130
10am	1.2	100	120	4pm	1.3	100	130
11am	1.2	100	120	5pm	1.2	100	120

The total volume of samples collected in the above example of a 12-hour composite would have been 1270 ml. If a composite is made from individually collected grab samples, then each of the individual grab samples should be shaken vigorously to provide a uniform mixture before the samples are pooled together. The pooled composite sample should also be thoroughly mixed immediately prior to obtaining a sample for analysis. Failure to do so may contribute to serious errors.

The amount to be collected during a specific sampling period can be calculated using the following formula:

$$\text{Amount of sample to collect} = \frac{\text{(Rate of flow, MGD, at time of sampling)(Total sample required, ml)}}{\text{(Number of samples collected)(Average daily flow, MGD)}}$$

Example Calculation:

			Data:
1.	Rate of flow at sample time	=	2 MGD
2.	Total sample required, ml	=	4000 ml
3.	Number of samples to collect	=	24
4.	Average daily flow	=	1.5 MGD
	Amount of sample to collect	=	$\frac{(2MGD)\ (4000ml)}{24)\ (1.5\ MGD)}$
		=	222.2 ml

4.2.3 Automatic Samplers

Automatic samplers are used to collect a series of grab samples on a constant time-constant volume principle or on a flow proportionate basis. The flow proportionate automatic samplers function by collecting a definite volume of sample each time a predetermined number of gallons of wastewater has passed the flow measuring device. This is the recommended approach to flow compositing at the Howard AFB WWTP.

In selecting automatic samplers and sampler locations, consideration should be given to the following:

1. Resistance of the sampler to the particular types of wastes being treated (i.e., wastes highly acidic or containing organic solvents).
2. Protection of the sampler from corrosive atmospheres, particularly in confined areas containing raw wastes.
3. That the sampler provide sufficient flow velocity in the intake tube to prevent settling of heavier solids particles.
4. That some type of sample-preservation is provided, either refrigeration or ice packs.
5. That sampler placement does not exceed the suction head capabilities of the sampler.
6. That compatible interfacing of the flow meter and sampler is possible.
7. That adequate safety is afforded personnel during recovery of the composite sample.
8. That a purge cycle is available to clean the intake line before and after each sample is collected.

As with all pieces of equipment, preventive maintenance and cleaning schedules should be followed. In particular, the intake tubes should be cleaned regularly to prevent solids buildup and periodic slough-off that can contaminate samples.

4.3 OTHER SAMPLING CONSIDERATIONS

4.3.1 Sample Preservation

Complete preservation of any sample, regardless of source, is almost impossible, and can never be achieved for every constituent in the sample. Preservation techniques can only, at best, retard the biological and chemical changes that inevitably continue after the sample is removed from the source. The methods of preservation are limited and are intended generally to (1) retard biological action, (2) retard hydrolysis of chemical compounds and complexes, and (3) reduce volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing.

Table 4.2 shows the various preservatives that may be used to retard changes in samples. Table 4.2 gives types of containers, preferred method of preservation and holding times for various test parameters.

4.3.2 Cleaning Sample Bottles

A common mistake made by those sampling is to use a bottle that has held "unknown" materials as a sample container. Often these containers have held oily or greasy substances which cling to the walls of the bottle and resist rinsing. Only new bottles or bottles that have been cleaned by acceptable methods in the laboratory should be used as sample bottles. It is good practice to designate bottles to be used exclusively to hold particular samples. These containers should be carefully labeled and used for no other purpose. These containers should be thoroughly rinsed before and after each use and periodically cleaned in the laboratory using only authorized laboratory cleaners.

4.3.3 Sample Volumes

Adequate volumes must be obtained to perform the desired analysis. The volume collected should be large enough to repeat the procedure if necessary. Never "dump" the remainder of a sample until your results are completed and considered to be satisfactory.

TABLE 4.2
RECOMMENDED SAMPLING SIZES AND PRESERVATION METHODS

Determination	Container	Minimum Sample Size mL	Preservation	Maximum Storage Recommended/Regulatory
Alkalinity	P, G	200	Refrigerate	24 h/14 d
Ammonia Nitrogen	P, G	500	H_2SO_4, Refrigerate	28 d/28 d
BOD	P, G	1000	Refrigerate H_2SO_4 to pH <2	6 h/48 h
Chlorine, residual	P, G	500	Analyze immediately	Analyze immediately
COD	P, G	250	H_2SO_4, Refrigerate	28 d/28 d
Fecal Coliform Bacteria	P, G	100	Refrigerate	6 h/6 h
Metals, general	P(A), G(A)	--	For dissolved metals filter immediately, add HNO_3 to pH <2	6 months/6 months
Chromium VI	P(A), G(A)	300	Refrigerate	24 h/48 h
Nitrogen, Total	P, G	1,000	H_2SO_4, Refrigerate	28 d/ 28 d
Nitrates	P. G.	100	Refrigerate	48 h/48 h
Nitrites	P, G	100	Refrigerate	48 h/48 h
Oil and Grease	G, wide-mouth calibrated	1000	Add H_2SO_4 to pH <2, refrigerate	28 d/28 d
Oxygen, dissolved:	G, BOD bottle	300		
Electrode			Analyze immediately	Analyze immediately
Winkler			Titration may be delayed after acidification	8 h/8 h
pH	P, G	100	Analyze immediately	Analyze immediately
Phosphorus, Ortho	P. G.	100	Filter	48 h/48 h
Phosphorus, Total	P. G.	100	H_2SO_4, Refrigerate	28 d/28 d
Solids	P, G	100	Refrigerate	7 d/7-14 d
Temperature	P, G	1,000	Analyze immediately	Analyze immediately

* See text for additional details. For determinations not listed, use glass or plastic containers; preferably refrigerate during storage and anayze as soon as possible. Refrigerate = storage at 4°C, in the dark. P = plastic (polyethylene or equivalent); G= glass; G(A) or P(A) = rinsed with 1+1 HNO_3; G(B) = glass, borosilicate; G(S) = glass, rinsed with organic solvents.

4.4 SAMPLING POINTS AND ANALYTICAL SCHEDULE

Table 4.3 presents the suggested sampling points at the Howard AFB WWTP. These points should be used consistently by all operators to help ensure the uniformity of all samples. Any change in sampling points or addition of sampling points must be communicated to all operators.

Table 4.4 presents a suggested sampling schedule for analyses run at the WWTP laboratory. This schedule can be adjusted as plant conditions dictate.

TABLE 4.3
HOWARD AFB WASTEWATER TREATMENT PLANT
SUGGESTED SAMPLING POINTS

Sample Type	Sample Point
Plant Influent	At plant headworks
Plant Secondary Effluent	From tap in Secondary Clarifier Collection Pipe
Plant Effluent	Chlorine contact chamber effluent
Aeration Tanks	Discharge of basins
Return Activated Sludge	Volute valves of RAS pumps
Aerobic Digester	From middle of tanks with aeration in progress
Upstream Creek Samples	0.5 miles above plant outfall.
Downstream Creek Samples	1.0 miles below plant outfall.
Downstream Creek Samples	1.5 miles below plant outfall.

TABLE 4.4
RECOMMENDED ANALYTICAL SCHEDULE

Sample	MON	TUES	WED	THUR	FRI	SAT	SUN
Influent COD[(a)]	--	--	--	--	--	--	--
Influent TKN[(a)]	--	--	--	--	--	--	--
Influent Phosphorus[(a)]	--	--	--	--	--	--	--
Influent BOD	--	--	C	--	C	--	--
Secondary Effluent BOD	--	--	C	--	C	--	--
Final Effluent BOD	--	--	C	--	C	--	--
Upstream Creek BOD	--	--	--	C	--	--	--
Downstream Creek BOD	--	--	--	C	--	--	--
Influent TSS	C	C	C	C	C	C	C
Influent VSS	C	C	C	C	C	C	C
Secondary Effluent TSS	C	C	C	C	C	C	C
Secondary Effluent VSS	C	C	C	C	C	C	C
Aeration TSS	G	G	G	G	G	G	G
Aeration VSS	G	G	G	G	G	G	G
Return Sludge TSS	C	C	C	C	C	C	C
Return Sludge VSS	C	C	C	C	C	C	C
Final Effluent TSS	C	C	C	C	C	C	C
Final Effluent VSS	C	C	C	C	C	C	C
Aeration Settleable Solids	G	G	G	G	G	G	G
Return Sludge Settleable Solids	G	G	G	G	G	G	G
Effluent Settleable Solids	G	G	G	G	G	G	G
Influent pH	G	G	G	G	G	G	G
Effluent pH	G	G	G	G	G	G	G
Effuent D.O.	G	G	G	G	G	G	G
Aeration D.O.	G	G	G	G	G	G	G
Upstream Creek D.O.	--	--	--	G	--	--	--
Downstream Creek D.O.	--	--	--	G	--	--	--
Digester Total Solids	G	--	G	--	--	--	--
Influent Temperature	G	G	G	G	G	G	G
Effluent Temperature	G	G	G	G	G	G	G
Drying Bed Sludge % Solids[2]	--	--	--	--	--	--	--
Dry Bed Sludge VS[2]	--	--	--	--	--	--	--
Drying Bed Sludge pH[2]	--	--	--	--	--	--	--
Effluent Chlorine Residual	G	G	G	G	G	G	G
Effluent Fecal Coliform	G	G	G	G	G	G	G

NOTE:
1. Sample Type: C = Composite, G = Grab
2. Drying Bed Sludge Analyses are performed on as-needed basis.
(a) Monthly

CHAPTER 5
LABORATORY TESTING

CHAPTER 5
LABORATORY TESTING

5.1 INTRODUCTION

Analytical testing conducted for the Howard AFB wastewater treatment plant will be generally performed by the WWTP operators. Off-site laboratory facilities may be occasionally used for certain analyses. Plant operators will use the results of the analytical tests performed at the WWTP to make decisions concerning the proper operation of the plant and for meeting the requirements of the Overseas Baseline Guidance Document parameters. For these reasons, it is necessary for all operators to have a general knowledge concerning the analytical procedures used at the plant. Such knowledge will allow the operators to evaluate the laboratory data and make determinations as to the validity of the data, and will provide the operators with a better understanding of the data collected and allow them to make more effective use of this data. By relating meaningful lab results to daily operation, the operator can effectively make process decisions, determine the efficiency of the process, predict and prevent problems that are developing, and determine causes of plant upsets.

The standard text used by most wastewater labs is entitled "Standard Methods for the Examination of Water and Wastewater." This text must be followed explicitly for results to be acceptable to regulatory agencies. Some operators find it difficult to understand and to follow "Standard Methods." This chapter is not to be considered as a substitute to "Standard Methods" but as a simplified guide for use by the Howard AFB operations staff. As operators master these techniques they should refer to "Standard Methods" to become aware of the possible pitfalls and interferences associated with these methods. This chapter deals primarily with the laboratory analyses to be performed at the Howard AFB wastewater treatment plant laboratory.

Other references to be consulted by the treatment plant operators for information concerning laboratory analyses include:

- Methods for Chemical Analysis of Water and Wastes, EPA.

- Simplified Laboratory Procedures for Wastewater Examination, Water Pollution Control Federation Publication No. 18.
- Operation of Wastewater Treatment Plants, Volume II, Sacramento State University.
- Hach Handbook of Water Analysis, Hach Chemical Company, 1979.

5.2 BIOCHEMICAL OXYGEN DEMAND ANALYSIS

5.2.1 Scope and Application

5.2.1.1 This method is applicable to the measurement of Biochemical Oxygen Demand (BOD) in drinking, surface and saline waters, domestic and industrial wastes.

5.2.1.2 Concentrations of BOD from 2 up to about 8 mg/liter may be measured directly. Multiplication by applicable dilution factors extends the range.

5.2.1.3 The effluent BOD from the Howard AFB WWTP is limited by the Overseas Environmental Baseline Guidance Document. The Overseas Environmental Baseline Guidance Document permit requires a specified frequency of analysis for BOD.

5.2.2 Methodology

5.2.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 5210-B, p. 5-2 of Standard Methods For The Examination of Water and Wastewater, 18th Edition; 1992.

5.2.2.2 Summary of Method

The method consists of filling with sample, to overflowing, an airtight bottle and incubating it at constant temperature for 5 days. Dissolved oxygen is measured initially and after incubation, and the BOD is computed from the difference between initial and final DO. A test flow diagram for the BOD test is provided in Figure 5.1

5.2.3 Safety Measures

The following are recommended safe job procedures for the BOD analysis.

5.2.3.1 Analyst should use a brush and pan to clean up broken glass.

5.2.3.2 Analyst should discard chipped glassware.

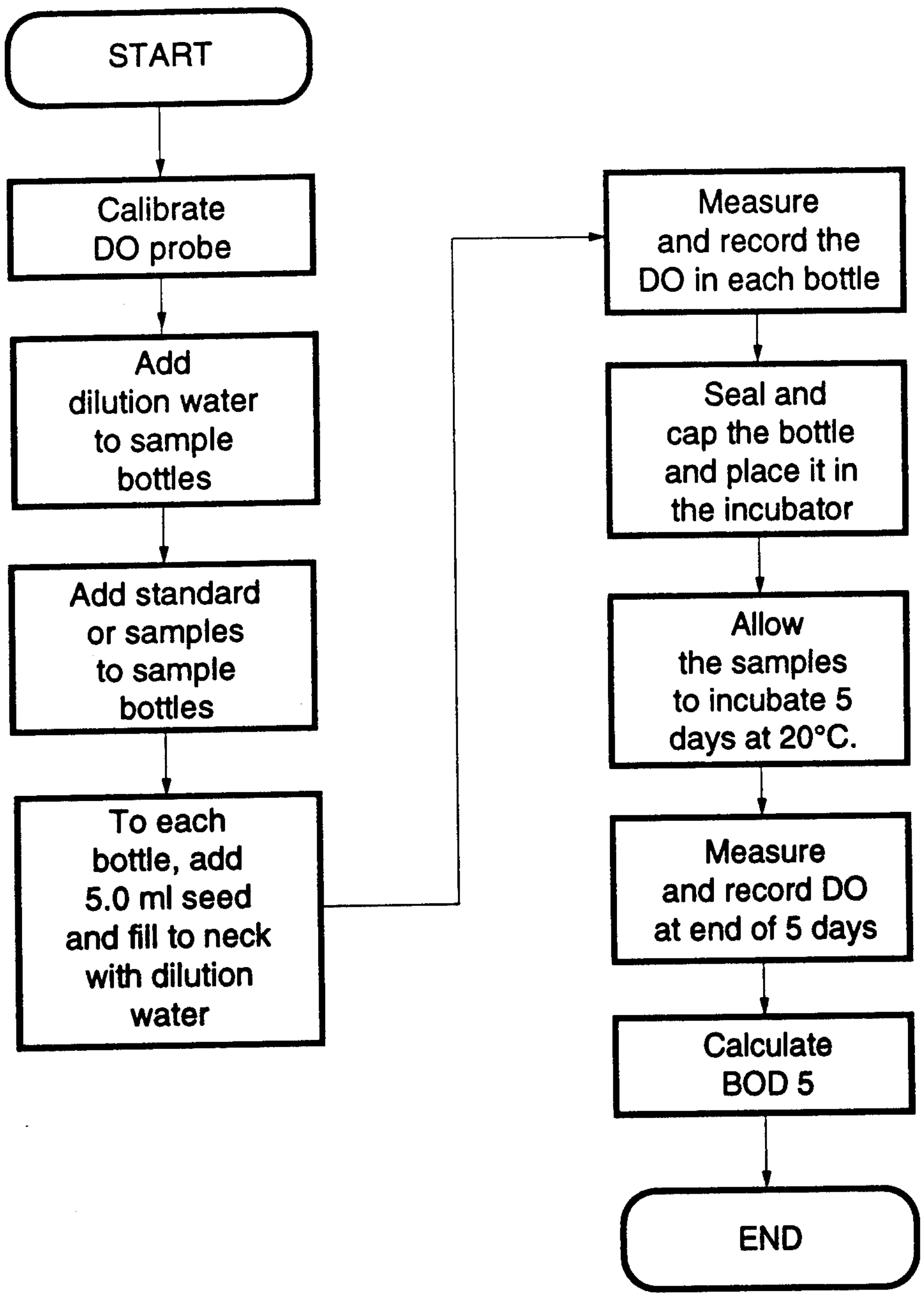
5.2.3.3 Analyst should wear rubber gloves when cleaning glassware and equipment.

5.2.3.4 Analyst should read MSDS for cleaning solutions and chemicals used.

5.2.3.5 Analyst should wear disposable gloves during testing procedures.

5.2.3.6 Analyst should keep work area dry.

TEST FLOW DIAGRAM
BIOCHEMICAL OXYGEN DEMAND



5.2.3.7 Analyst should not use frayed electrical cords.

5.2.3.8 Analyst should wear safety glasses during analysis.

5.2.4 Supporting Materials and Equipment

5.2.4.1 Apparatus and Materials

1. Dissolved oxygen meter w/self stirring probe
2. BOD bottles - 300 ml capacity
3. BOD dilution water carboy, 4 liters
4. Erlenmeyer flask, 500 ml
5. Beaker, 250 ml
6. Seven each 10-ml measuring pipets
7. Aquarium pump
8. Incubator thermostatically controlled at 20°C ± 0.5°
9. Thermometer graduated in 0.1 degree C° increments

5.2.4.2 Reagents and Standards

1. Laboratory reagent water - distilled water in which an interference is not observed at the method detection limit.
2. Phosphate buffer solution - Dissolve 8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g $Na_2HPO_4.7H_2O$, and 1.7 g NH_4Cl in about 500 mL distilled water and dilute to 1 L.
3. Magnesium sulfate solution - Dissolve 22.5 g $MgSO_4 \bullet 7H_2O$ in distilled water and dilute to 1 L.
4. Calcium chloride solution - Dissolve 27.5 g $CaCl_2$ in distilled water and dilute to 1 L.
5. Ferric chloride solution - Dissolve 0.25 g $FeCl_3 \bullet 6H_2O$ in distilled water and dilute to 1 L.
6. Glucose-glutamic acid solution - Dry reagent-grade glucose and reagent-grade glutamic acid at 103°C for 1 hour. Add 150 mg glucose and 150 mg glutamic acid to distilled water and dilute to 1 L. Prepare fresh immediately before use.

7. Manganese Sulfate solution - Dissolve 480 g $MnSO_4 \bullet 4H_2O$, 400 g $MnSO_4 \bullet 2H_2O$, or 364 g $MnSO_4 \bullet H_2O$ in distilled water, filter, and dilute to 1 L. The manganese sulfate solution should not give a color with starch when added to an acidified solution of potassium iodide.

8. Alkali-iodide-azide reagent - Dissolve 500 g sodium hydroxide and 135 g sodium iodide in distilled water and dilute to 1 L. To this solution add 10 g sodium azide dissolved in 40 mL distilled water.

5.2.5 Calibration of Dissolved Oxygen (D.O.) Meter

5.2.5.1 Place the D.O. probe in open atmosphere.

5.2.5.2 Turn the D.O. meter control knob to zero and zero the meter.

5.2.5.3 Turn the control knob to full scale and adjust the needle position to N.45/15.

5.2.5.4 Turn the control knob to calibrate O_2.

5.2.5.5 Adjust the meter needle with the calibrate knob to read at the "sea level" mark.

5.2.5.6 Wait 15 minutes and readjust to "sea level" if necessary.

5.2.5.7 Place probe into a sample of known temperature. Turn control dial to temperature function and turn dial to correct temperature.

5.2.6 Alternate D.O. Meter Calibration Method

5.2.6.1 Pour 200 ml of distilled water into a 250-ml beaker

5.2.6.2 Saturate distilled water with oxygen at 20°C by bubbling air with the aquarium air pump. Keep the saturation process running all the time. This process will require maintaining the system in an incubator.

5.2.6.3 Pour 100 ml of saturated water into a 150 ml beaker and add a magnetic stirrer.

5.2.6.4 Read temperature of the saturated water. With the temperature value determine the dissolved oxygen saturation concentration at sea level. These values are generally printed in the back of the D.O. meter.

5.2.6.5 Immerse the D.O. probe into the 100 ml of saturated water and start mixing.

5.2.6.6 Set D.O. meter in calibration.

5.2.6.7 Read D.O. concentration. If value read is different from saturation and concentration (Step #4), adjust to read the later concentration.

5.2.6.8 Once the D.O. meter is calibrated turn knob to READ position.

5.2.7 Procedure

5.2.7.1 Set out required number of 300-ml bottles to be set up for a 5-day BOD.

5.2.7.2 BOD bottles must be rinsed with acid cleaning solution after each use.

1. Coat inside surfaces of bottles with chromic acid cleaning solution.
2. Drain acid back into its 5-pt storage bottle. Acid can be reused until it develops a green tint.
3. Rinse BOD bottles 3 times with tap water and 3 times with distilled water.
4. Bottles must be thoroughly drained prior to use.

5.2.7.3 Each bottle must be numbered to permit identification.

5.2.7.4 Prepare BOD dilution water.

1. Place desired volume of distilled water in suitable size dilution water carboy.
2. Add the appropriate volume of solution (usually 1 ml for each liter) or powder pillow contents of magnesium sulfate, calcium chloride, ferric chloride and phosphate buffer. Follow the supplier's instructions. When pipeting liquid nutrient solutions, use separate pipets for each solution to avoid solution contamination.
3. Make up enough dilution water for one day's use 24 hours in advance.
4. Dilution water bottle and aspirator tubing should be cleaned with laboratory detergent and hot water and rinsed thoroughly.
5. Change aspirator tubing whenever there is the slightest evidence of algae growth in the tube but no less frequently than every 3 weeks.
6. Store dilution water inside the BOD incubator for 24 hours before use, but never place freshly distilled, hot water in the incubator. Instead, store a larger stock of distilled water in the dark, inside a laboratory cabinet to prepare dilution water from.

5.2.7.5 Siphon the dilution water into 300-ml bottle until the bottles are half-full.

5.2.7.6 To the half-full bottles add with a pipet the desired quantity of sample.

5.2.7.7 Fill the bottles to the neck with the dilution water and stopper so there are no air bubbles.

5.2.7.8 The following procedures present specific examples of sample dilution and bottle set-ups that might be utilized at the Howard WWTP:

1. Fill two (2) 300-ml bottles with dilution water. One is for a Dissolved Oxygen test which is run the same day. The second one is the dilution water blank and is to be set in the incubator with the rest of the samples.

2. Fill six (6) 300-ml bottles marked "Influent" with sample and dilution water.

   Bottles #1a and 1b - 3.0 ml sample (1% dilution)
   Bottles #1c and 1d - 9 ml sample (3% dilution)
   Bottles #1e and 1f - 15 ml sample (5% dilution)

3. Fill six (6) 300-ml bottles marked "Secondary Effluent" with sample and distilled water.

   Bottles #2a and 2b - 45 ml
   Bottles #2c and 2d - 75 ml
   Bottles #2e and 2f - 105 ml

4. Fill six (6) 300-ml bottles marked "Plant Effluent" with sample and dilution water.

   Bottles #3a and 3b - 75 ml sample
   Bottles #3c and 3d - 105 ml sample
   Bottles #3e and 3f - 150 ml sample

5. Fill six (6) 300-ml bottles marked "Stream" 0.5 miles UP with sample and dilution water.

   Bottles #4a and 4b - 75 ml sample
   Bottles #4c and 4d - 105 ml sample
   Bottles #4e and 4f - 150 ml sample

6. Fill six (6) 300-ml bottles marked "Stream" 1.0 miles DOWN with sample and dilution water.

Bottles # 5a and 5b - 75 ml sample
Bottles # 5c and 5d - 105 ml sample
Bottles # 5e and 5f - 150 ml sample

7. Fill four (4) 300-ml bottles marked "Stream" 1.5 mile DOWN with sample and dilution water.

Bottles #6a and 6b - 75 ml sample
Bottles #6c and 6d - 105 ml sample
Bottles #6e and 6f - 150 ml sample

5.2.7.9 Run D.O. on the "a" , "c" and "e" sets of bottles at the time of set up. The "b", "d" and "f" sets of bottles are incubated for 5 days at 20°C.

5.2.7.10 On removal from the incubator, Dissolved Oxygen is determined on all samples and recorded on the bench sheets.

5.2.8 Calculations for BOD:

$$\frac{\text{(Initial DO of Diluted Sample - DO of Sample after 5 days)}}{\text{Percent of Sample Added}} = \text{mg/L 5 Day BOD}$$

5.2.9 Special Considerations:

5.2.9.1 Weekly, check the effectiveness of the seed and presence of toxic materials in dilution water by incubating a Glucose-Glutamic Acid or a Potassium Acid Phthalate standard. (See Standard Methods.)

5.2.9.2 For each ten samples analyzed, a duplicate should be run to check the precision of the analysts and their procedures and techniques.

5.2.9.3 Dilution water blanks should not exceed 0.2 mg/L of D.O. depletion at the end of 5 days of incubation. Do not use dilution water blank depletion in the BOD calculation determination.

5.2.9.4 Dilutions must result in a residual D.O. after 5 days of incubation of at least 1.0 mg/L and a D.O. uptake of at least 2.0 mg/L. If dilutions do not fit within these criteria they should be adjusted up or down during the next setup.

5.2.9.5 Check and log incubator temperature at least daily.

5.2.9.6 Samples containing residual chlorine must be dechlorinated and seeded prior to set-up procedure. (See "Standard Methods.")

5.29.7 Equilibrate sample temperatures to 20°C prior to setting up sample dilutions. Samples should be thoroughly mixed prior to removing aliquots.

5.2.10 Quality Assurance/Quality Control

5.2.10.1 QA/QC Samples

One duplicate of the plant effluent, one standard, and one distilled water blank will be run each day that BOD is analyzed.

5.2.10.2 Acceptability Criteria

Dilutions should have a minimum of 2.0 mg/L DO depletion and at least 1.0 mg/L remaining after the 5-day incubation period.

5.2.11 Documentation and Reporting

5.2.11.1 Internal Documentation

The analyst will fill out the laboratory sheet for BOD for each sample analyzed and record the following information. The logbook entries should be clearly labeled.

a. Sample Date and Time

b. Sample Location or Identity

c. Date and Time of Analysis

d. Identity of Analyst

e. Readings for standards.

f. Sample Results in mg/L BOD

g. Blank, Duplicate, and Standard Results.

h. Volume of seed added to dilutions and control.

5.2.11.2 Reporting

All final data from the laboratory bench data logbook will be entered onto the Utility Log and Supplemental Utility Log.

5.2.11.3 Maintenance

All glassware will be cleaned as described in the procedure each day that the BOD analysis is run.

5.3 TOTAL SUSPENDED SOLIDS ANALYSES

5.3.1 Scope and Application

This method covers the determination of total suspended solids. Total suspended solids is a measure of the effectiveness and efficiency of many wastewater treatment processes and plants as a whole. The effluent total suspended solids from the Howard AFB WWTP is limited by the Overseas Environmental Baseline Guidance Document. The Overseas Environmental Baseline Guidance Document requires a specified frequency of analysis for total suspended solids. Suspended solids encompass the portion of total solids retained after filtration.

5.3.2 Methodology

5.3.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 2540 D, p. 2-56 of Standard Methods For The Examination of Water and Wastewater, 18th Edition; 1992.

5.3.2.2 Summary of Method

A well-mixed sample is filtered through a weighed, standard, glass-fibered filter, and the residue retained on the filter is dried to a constant weight at 103-105°C. The increase in weight of the filter represents the total suspended solids. A test flow diagram for the total suspended solids test is provided in Figure 5.2.

5.3.3 Safety Measures

The following are recommended safe job procedures have been developed for the total suspended solids test.

5.3.3.1 Analyst should use a brush and pan to clean up broken glass.

5.3.3.2 Analyst should discard chipped glassware.

5.3.3.3 Analyst should wear rubber gloves when cleaning glassware and equipment.

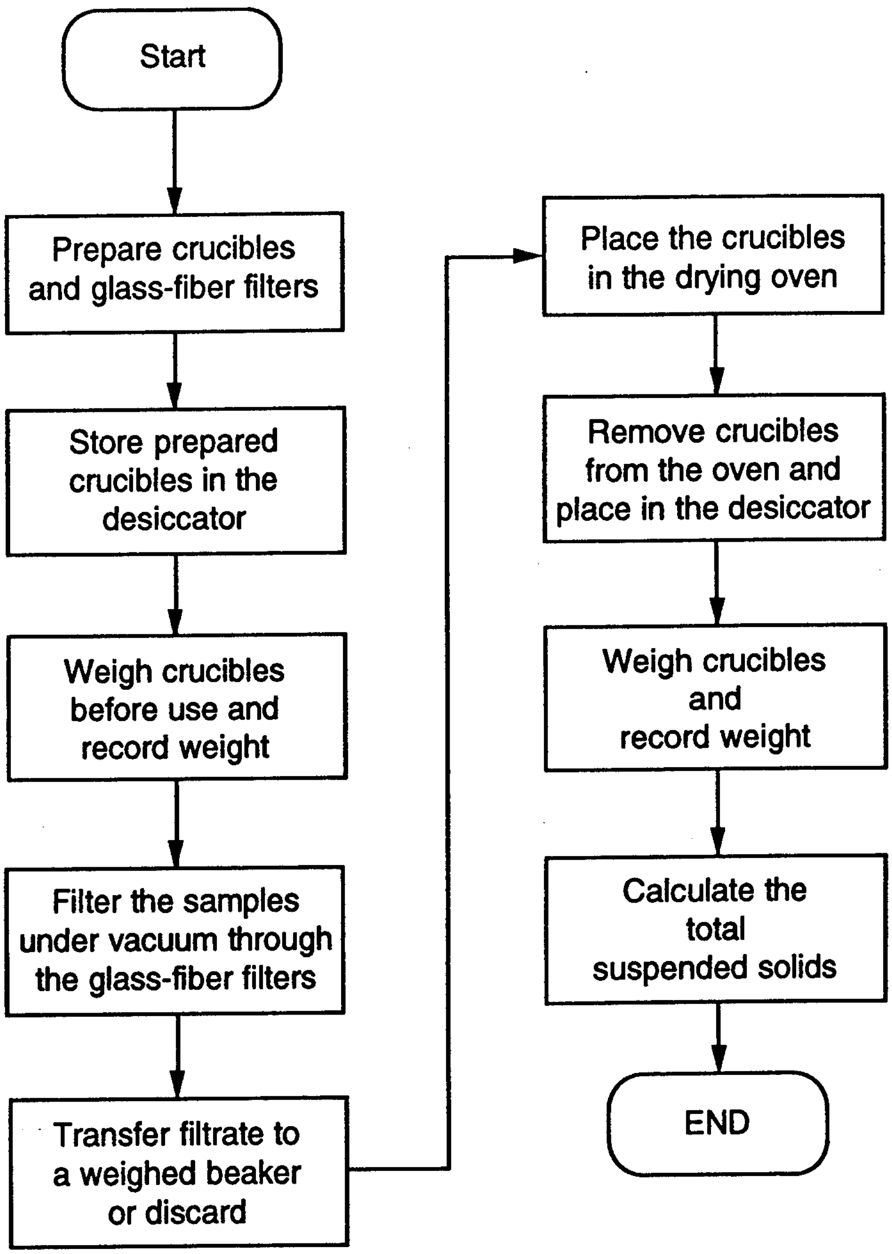
5.3.3.4 Analyst should read MSDS for cleaning solutions and chemicals used.

5.3.3.5 Analyst should wear gloves when handling hot objects.

5.3.3.6 Analyst should use tongs to handle crucibles.

Figure 5.2

TEST FLOW DIAGRAM
TOTAL SUSPENDED SOLIDS



5.3.3.7 Analyst should wear disposable gloves during testing procedures.

5.3.3.8 Analyst should keep work area dry.

5.3.3.9 Analyst should not use frayed electrical cords.

5.3.3.10 Analyst should wear safety glasses while performing procedures.

5.3.4 Supporting Materials and Equipment

5.3.4.1 Apparatus and Materials

1. Glass-fiber filter disks without organic binder, with a pore size of 0.7 - 1.2 microns.
2. Gooch crucible, 25-mL to 40-mL capacity, with Gooch crucible adapter.
3. Filtration apparatus with reservoir.
4. Suction flask, of sufficient capacity for sample size selected.
5. Drying oven, for operation at 103 to 105°C with thermometer bulb inserted into a beaker of sand inside oven.
6. Desiccator, provided with a desiccant containing a color indicator for moisture concentration.
7. Analytical balance, capable of weighing to 0.1 mg.
8. Muffle furnace for operation at 550°C ± 50°C.

5.3.4.2 Reagents and Standards

1. Laboratory reagent water - distilled water in which an interference is not observed at the method detection limit.

5.3.5 Analytical Procedure

5.3.5.1 Prepare Crucibles and Filters

1. Connect the vacuum apparatus and turn it on.
2. Place a new filter rough side up in a crucible.
3. Place the crucible on the vacuum apparatus.
4. Rinse the crucible and filter by pouring 20 mL of distilled water into the crucible.
5. Allow the water to be pulled through the filter.

6. Again add 20 mL of distilled water to the crucible.
7. Allow the water to be pulled through the filter.
8. A third time add 20 mL of distilled water to the crucible.
9. After the water has been pulled through the filter, remove the crucible from the vacuum apparatus.
10. Place the crucible in the drying oven.
11. Repeat steps 2 through 9 for each crucible.
12. Turn off and disconnect the vacuum apparatus.
13. Allow the crucibles to dry overnight at 103-105°C.
14. Remove the crucibles from the oven using tongs.
15. Place the crucibles in the desiccator.
16. Allow the crucibles to cool for 2 hours before using.

5.3.5.2 Sample Analysis

1. Using tongs, take a prepared crucible from the desiccator.
2. Weigh the crucible to the nearest .0001 gram.
3. Record the weight, in grams, of the crucible as A.
4. Connect the vacuum apparatus and turn it on.
5. Place the crucible on the vacuum apparatus.
6. Thoroughly mix the sample.
7. Measure the sample in a clean graduated cylinder.
8. Record the volume, in milliliters, of the sample as B.
9. Pour the sample slowly into the crucible. Do not overfill the crucible.
10. After all of the sample has been poured into the crucible, rinse the graduated cylinder with 10 mL of distilled water and pour the rinse water into the crucible.
11. Rinse the graduated cylinder a second time with 10 mL of distilled water and pour the rinse water into the crucible.

12. Rinse the graduated cylinder a third time with 10 mL of distilled water and pour the rinse water into the crucible.
13. Remove the crucible from the vacuum apparatus after all the water has been pulled through the filter.
14. Place the crucible in the drying oven.
15. Repeat steps 1 through 13 for each sample.
16. Turn off and disconnect the vacuum apparatus.
17. Allow the crucibles to dry to a constant weight (usually 1 hour.)
18. Remove the crucibles from the drying oven using tongs.
19. Place the crucibles in the desiccator.
20. After 2 hours in the desiccator, use tongs to remove each crucible from the desiccator and weigh the crucible to the nearest .0001 gram.
21. Record the weight, in grams, of the crucible as C.
22. Remove the filter from the crucibles.
23. Rinse the crucibles with deionized water.
24. If volatile suspended solids (VSS) are also to be analyzed, place the filter in the muffle furnace at 550 ± 50°C for 15 to 20 minutes.
25. Remove crucible from muffle furnace using tongs.
26. Let crucibles cool over the lab bench for 5 minutes.
27. Place crucible in the desiccator.
28. After one hour in the desiccator use tongs to remove crucible from desiccator and weight it to the nearest 0.0001 gram.
29. Record the weight, in grams, of the crucible as D.

5.3.6 Calculation

5.3.6.1 Calculate the total suspended solids using the following equation:

$$\text{mg/L TSS} = \frac{(A - B)}{C}$$

A = Final weight of crucible filter, and residue, mg.

B = Initial weight of crucible and filter, mg.

C = Sample volume, L.

5.3.6.2 Calculate the volatile suspended solids using the following equation:

$$\text{mg/L TSS} = \frac{(A - D)}{C}$$

A = Final weight from TSS determination, mg.

D = Final weight of crucible, filter and residue after ashing, mg.

C = Sample volume, L.

5.3.7 Quality Assurance/Quality Control

5.3.7.1 QA/QC Samples

One duplicate of the plant effluent will be run each day the TSS analyses are performed. A distilled water blank will be analyzed each day.

5.3.7.2 Acceptability Criteria

Sample residue yields should be between 2.5 and 200 mg.

5.3.8 Documentation and Reporting

5.3.8.1 Internal Documentation

The analyst will fill out the laboratory bench data book for TSS for each sample analyzed and record the following information. The logbook entries should be clearly labeled.

a. Sample Date and Time

b. Sample Location or Identity

c. Date and Time of Analysis

d. Identity of Analyst

e. Sample Volume

f. Weight of Crucible and Filter

g. Weight of Crucible, Filter and Dried Residue

h. Total Suspended Solids in mg/L

i. Weight of crucible, filter and ash

j. Volatile suspended solids, mg/l

5.3.8.2 Analytical Balance Calibration

To ensure proper balance calibration, the following items should be recorded in bench data book.

1. Zero Check
2. Actual Mass of Standard Weight
3. Read-Out Value of Standard Weight
4. Date and Analyst

5.3.8.3 Drying Oven

Records should be maintained of the drying oven performance including:

a. Temperature Reading (Once Per Day)

b. Length of Time Used For Samples and Crucible Preparation

c. Date and Analyst

5.3.8.4 Reporting

All final data from the laboratory bench sheet will be entered onto the Utility Log and Supplemental Utility Log.

5.3.9 Maintenance

1. The analytical balance should be serviced by a manufacturer's representative twice per year.
2. The analytical balance pan should be dusted daily and should removed and cleaned with acetone bimonthly.
3. The interior of the drying oven should be cleaned bimonthly.
4. All glassware and filtration apparatus should be cleaned daily.

5.4 pH ANALYSES

5.4.1 Scope and Application

This method covers the determination of pH in aqueous samples and is applicable to drinking, surface, and saline waters, domestic and industrial wastes. The effluent pH from the Howard AFB WWTP is limited by the Overseas Environmental Baseline Guidance Document. The Overseas Environmental Baseline Guidance Document requires a specified frequency of analysis for pH.

5.4.2 Methodology

5.4.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 4500-H, p. 4-65 of Standard Methods For The Examination of Water and Wastewater, 18th Edition; 1992 and Method E150.1, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, March 1983.

5.4.2.2 Summary of Method

A well-mixed sample is poured into a beaker with a magnetic stir bar. A pH probe is lowered into the sample, and the pH and temperature are read and recorded. A test flow diagram is provided in Figure 5.3.

5.4.3 Safety Measures

The following are recommended safe job procedures have been developed for the pH test.

5.4.3.1 Analyst should use a brush and pan to clean up broken glass.

5.4.3.2 Analyst should discard chipped glassware.

5.4.3.3 Analyst should wear rubber gloves when cleaning glassware and equipment.

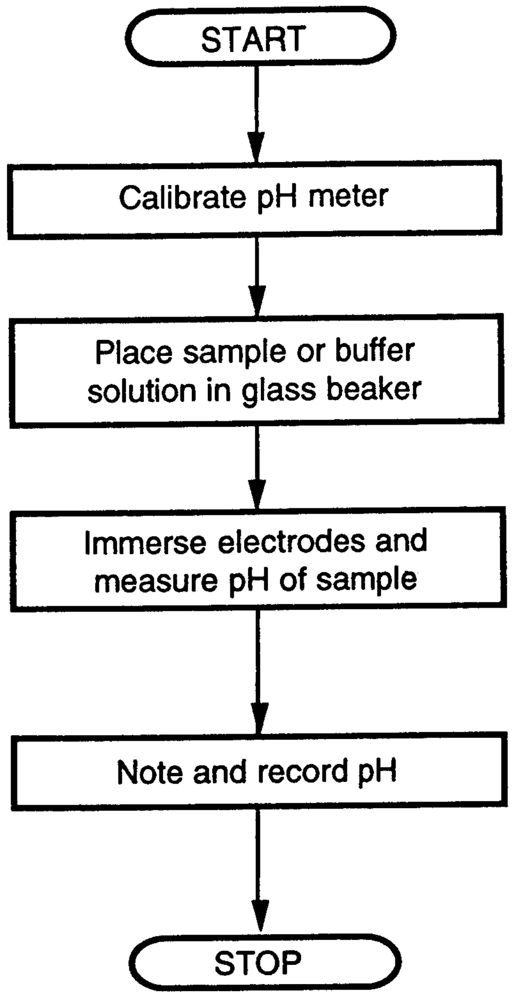
5.4.3.4 Analyst should read MSDS for buffer solutions.

5.4.3.5 Analyst should wear disposable gloves during testing procedures.

5.4.3.6 Analyst should keep work area dry.

5.4.3.7 Analyst should not use frayed electrical cords.

TEST FLOW DIAGRAM
pH ELECTROMETRIC MEASUREMENT



5.4.4 Supporting Materials and Equipment

5.4.4.1 Apparatus and Materials

1. pH meter.
2. Pyrex or Kimax beakers, 50-mL capacity.
3. Magnetic stirrer.
4. Magnetic stir bars.

5.4.4.2 Reagents and Standards

1. Distilled water in which an interference is not observed at the method detection limit.
2. pH 4 buffer.
3. pH 7 buffer.
4. pH 10 buffer.

5.4.5 Analytical Procedure

5.4.5.1 Calibration of pH Meter

1. Pour out the old pH buffers.
2. Turn the function knob on the pH meter to the pH position.
3. Raise the probe from the storage solution and rinse the probe with deionized water.
4. Blot the probe dry.
5. Pour 40 mL of fresh pH 7 buffer into the marked 50-mL beaker.
6. Place a stir-bar in the beaker of pH 7 buffer and place the beaker on the stirrer.
7. Turn the control knob on the magnetic stirrer on.
8. Lower the probe into the pH 7 buffer.
9. Allow time for the reading to stabilize (2 to 5 minutes).
10. Record the reading from the display.
11. Turn the "calib" knob until the display shows 7.00.

12. Record the calibration setting of 7.0.
13. Raise the probe from the pH 7 buffer solution and remove the beaker from the stirrer.
14. Rinse the probe with deionized water and blot the probe dry.
15. Place a stir-bar in the beaker of pH 4 buffer and place the beaker on the stirrer.
16. Lower the probe into the pH 4 buffer.
17. Allow time for the reading to stabilize.
18. Adjust the reading to 4.00, using the TEMP°C/slope knob.
19. Record the slope setting of 4.00.
20. Raise the probe from the pH 4 buffer and remove the beaker from the stirrer.
21. Rinse the probe with deionized water and blot the probe dry.

5.4.5.2 Sample Analysis

1. Turn the magnetic stirrer on.
2. Raise the probe from the storage solution and rinse the probe with deionized water.
3. Blot the probe dry.
4. Pour 40 mL of sample into a clean 50-mL beaker.
5. Place a stir bar in the beaker.
6. Place the beaker on the magnetic stirrer.
7. Lower the pH probe into the sample.
8. Allow time for the reading to stabilize (2 to 5 minutes).
9. Record the reading from the display.
10. Raise the pH probe out of the sample.
11. Rinse the pH probe with deionized water.
12. Repeat steps 4 through 11 for each additional sample.
13. Lower the pH probe into the storage solution.

14. Turn the magnetic stirrer off.

15. Turn the pH meter function knob to the "STD-BY" position.

5.4.6 Calculation

5.4.6.1 No calculation is required for pH determinations.

5.4.7 Sample Volumes

5.4.7.1 A sample volume of 40 mL will be utilized under this procedure.

5.4.8 Quality Assurance/Quality Control

5.4.8.1 QA/QC Samples

One duplicate of the plant effluent will be run each day.

5.4.8.2 Acceptability Criteria

Buffers should be ± 0.1 pH unit of the correct value.

5.4.9 Documentation and Reporting

5.4.9.1 Internal Documentation

The analyst will fill out the laboratory bench sheet for pH for each sample analyzed and record the following information. The logbook entries should be clearly labeled.

1. Sample Date and Time
2. Sample Location or Identity
3. Date and Time of Analysis
4. Identity of Analyst
5. Sample Volume
6. pH
7. Temperature in °C.

5.4.9.2 pH Meter Calibration

To ensure proper pH meter calibration, the following items should be recorded in bench data book.

1. pH 7 Buffer Calibration Reading

2. pH 4 Slope Reading
3. Date and Analyst

5.4.9.3 Reporting

All final data from the laboratory bench sheet will be entered onto the Utility Log and Supplemental Utility Log.

5.4.10 Maintenance

The pH Meter should be serviced by a manufacturer's representative twice per year. All glassware should be cleaned daily.

5.5 FECAL COLIFORM MEMBRANE FILTER PROCEDURE

5.5.1 Scope and Application

This method covers the determination of fecal coliform bacteria density. Fecal coliform bacteria are an indicator organism that provides a measure of the effectiveness of the disinfection process of wastewater treatment plant.

5.5.2 Methodology

5.5.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 9222D, P9-60 of Standard Methods for the Examination of Water and Wastewater, 18th Ed., 1992.

5.5.2.2 Summary of Method

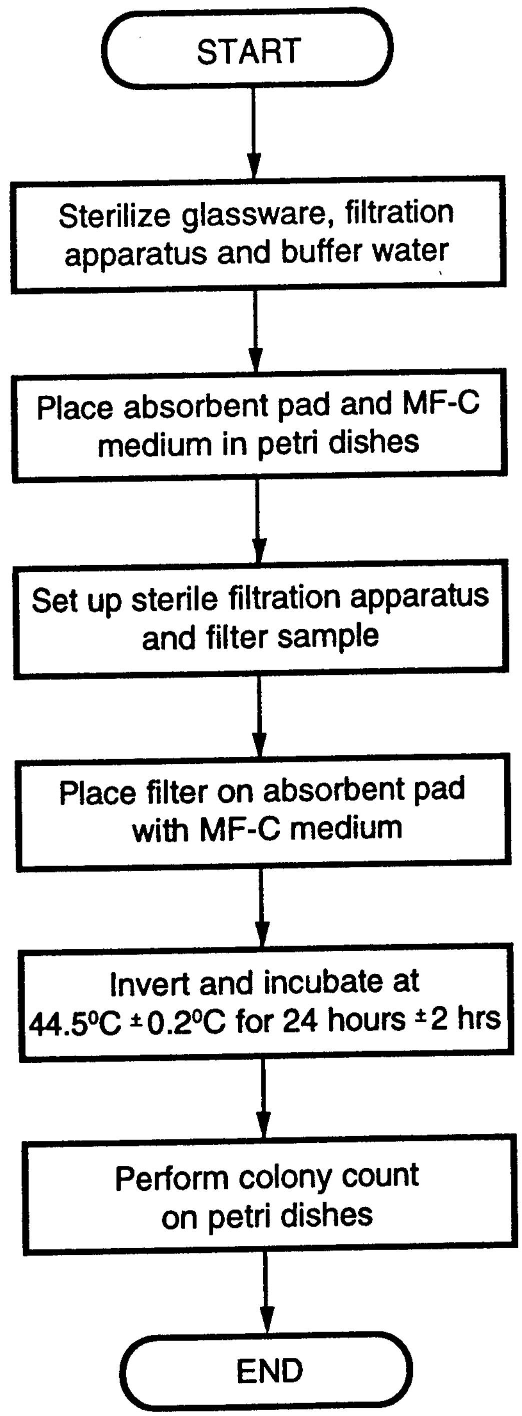
The Membrane Filter (MF) Coliform Method is a fast, simple way of estimating bacterial populations in water. A well-mixed sample volume is passed through a membrane filter with a pore size small enough (0.45 microns) to retain the bacteria present. The filter is placed on an absorbent pad (in a petri dish) saturated with a culture medium that is selective for coliform growth. The petri dish containing the filter and pad is incubated, upside down, for 24-hours at 44.5°C ± 0.2°C. After incubation, the colonies that have grown are identified and counted by using a low-power microscope. A test flow diagram is provided in Figure 5.4.

5.5.3 Safety Measures

The following safety procedures have been developed for the fecal coliform bacteria test:

1. Analyst should use a brush and pan to clean up broken glass.
2. Analyst should discard chipped glassware.
3. Analyst should wear rubber gloves when cleaning glassware and equipment.
4. Analyst should read MSDS for cleaning solutions and chemicals used.
5. Analyst should wear disposable gloves during testing procedures.
6. Analyst should keep work area dry.
7. Analyst should not use frayed electrical cords.

TEST FLOW DIAGRAM
FECAL COLIFORM BACTERIA



8. Analyst should keep alcohol away from combustion sources.

5.5.4 Supporting Materials and Equipment

5.5.4.1 Apparatus and Materials

1. Clippers, large
2. Graduated cylinders, 100 ml
3. Petri dishes, sterile
4. Filter holder
5. Filter pump
6. Membrane filters, pre-sterilized in lab autoclave or commercially available
7. Filter flask, 500 ml
8. Forceps, flat-end, 110 mm
9. Pads, sterile, commercially available or pre-sterilized in lab autoclave
10. Pipets, sterile, 10 ml
11. Tubing, rubber
12. Incubator - water bath or heat sink 44.5 ± 0.2°C
13. Microscope, 10x - 15x magnification

5.5.4.2 Reagents

1. Dechlorinating Reagent Powder Pillows or 10% Solution of Sodium Thiosulfate.
2. M-FC Medium, commercially prepared
3. 70% Isopropyl Alcohol
4. Phosphate buffer solution

5.5.5 Analytical Procedures

5.5.5.1 Sterilization of Equipment

1. Before starting the test, pre-heat the autoclave to 121° and wash all sample bottles, graduated cylinders and containers, forceps, filter flasks, filter holder in hot, soapy water. Rinse several times with tap water then with

demineralized water and dry thoroughly. Prior to sterilization, prepare items as follows, then sterilize in an autoclave at 121°C for 15 minutes.

2. Sample bottles should be capped and covered with brown Kraft paper.
3. Forceps should be wrapped in brown paper and sealed with masking tape.
4. The opening of the graduated cylinder and the filter flask should be covered with metal foil or brown paper.
5. The two parts of the filter should be wrapped separately in brown paper and sealed with masking tape.

5.5.5.2 Preparation of Phosphate Buffer Solution

1. Phosphate Buffer. The phosphate buffer is used to dilute and rinse samples. This solution must be sterile, because any organisms present in the buffer may interfere with coliform counts. Prepare the buffer by:
2. Stock Solution I. Dissolve 34.0 grams of potassium dihydrogen phosphate (KH_2PO_4) in 500 ml of laboratory pure water. Adjust the pH to 7.2 with 1 N NaOH. Dilute to 1000 ml with laboratory pure water to produce 1 L of stock buffer solution. Refrigerate stock buffer. Discard it if it becomes turbid.
3. Stock Solution II. Dissolve 28 grams of magnesium chloride ($MgCl_2$) or 81.4 gram of $MgCl_2.6H_2O$) in 1 L of laboratory pure water.
4. Working Solution. Add together 1.35 ml of Stock Solution I and 5.0 ml of Stock Solution II and dilute to 1 L with laboratory pure water in an aspirator bottle. Mix completely.

5.5.5.3 Equipment and Material Preparation

1. Prior to preparing the sample set-ups, wipe down the countertop being used with Isopropyl alcohol.
2. Set out petri dish for each sample to be tested. Put sterile pad into each dish.
3. Prior to opening, dip the etched end of a M-FC Medium Ampule in 70% Isopropanol Alcohol for 1 minute. Allow the alcohol to evaporate.
4. Snap open the neck of the Ampule, being careful not to touch the area surrounding the etched mark.
5. Pour the M-FC Medium evenly over the absorbent pad in the petri dish.

6. Unwrap the forceps, filter holder, filter flask and graduated cylinder.
7. Attach the rubber tubing to the filter pump and place the bottom half of the filter holder in the neck of the filter flask.
8. Dip the end of the forceps in 70% Isopropyl Alcohol for one minute.
9. Open a package of sterile membranes. Using the sterile forceps, carefully center a sterile filter on the porous plate of the filter apparatus. Be sure the grid side is up.
10. Carefully put the top half of the filter holder in place over the filter and clamp the holder together.

5.5.5.4 Sample Preparation and Filtration

1. Collect at least 250 ml of water from a representative effluent site. Sample containers should be wide mouth glass or polypropylene bottles that have been carefully cleaned and rinsed with demineralized water, then sterilized in the autoclave. To avoid contamination during sampling, do not handle the stopper or neck of the sample bottle. Keep container closed until ready to use then fill without rinsing and replace the cap immediately. Be sure to leave at least 1-inch of head space above the sample in the container. For chlorinated samples, add the contents of one Dechlorinating Reagent Pillow or 0.2 ml of a 10% solution of Sodium Thiosulfate to each sample bottle to counter any residual chlorine that may be present prior to sterilizing in the autoclave.
2. Shake the sample bottles to distribute the bacteria evenly, then measure the sample into the sterile graduated cylinder. Add a small volume of sterile buffer dilution water to filter funnel and graduated cylinder.
3. Prepare a minimum of three dilutions. Dilutions of 10% (10 ml), 1% (1 ml) and 0.1% (0.1 ml) should be used initially. If necessary, dilutions should be adjusted to obtain membrane filter counts between 20 and 60 colonies. A sterile buffer dilution water blank should be prepared first, then the smallest dilution next, and so forth (weakest to strongest). A known positive sample should be set up last to test for the viability of the test.

4. Pour the sample into filter holder, turn on vacuum and filter. Rinse the filter holder with three 20- to 30-ml portions of sterile buffer dilution water. Allow to vacuum. Turn off the pump.

5. Dip forceps in 70% Isopropyl Alcohol for 1 minute, then air dry. Remove the filter holder and immediately peel off the filter with sterile forceps. Place the filter on the absorbent pad. Avoid entrapping air under the filter when placing it on the absorbent pad.

6. Replace cover on petri dish and label. Inspect membrane filter after 20 seconds to insure even coloration. Place the petri dishes in the incubator in an inverted position and incubate for 22 to 24 hours at 44.5°C ± 0.2°C.

5.5.5.5 Counting Membrane Filter Colonies

Membrane Filter Colonies are best counted with a magnification of 10 to 15 diameters and the light source adjusted to give maximum sheen. A binocular wide field dissecting microscope is recommended as the best optical system. However, a small fluorescent lamp with magnifier is acceptable. Colony differentiation is best made with white fluorescent light.

5.5.5.6 Calculation of Coliform Density

Report the Coliform Density in terms of coliforms/100 ml. Compute the count, using membrane filters with 20-60 coliform colonies per membrane, by the following equation:

$$\text{Coliform colonies/100 ml} = \frac{\text{Coliform Colonies counted}}{\text{ml Sample Filtered}} \times 100$$

5.5.6 Quality Assurance/Quality Control

5.5.6.1 QA/QC Samples

In addition to the plant effluent, a sterile dilution water blank should be analyzed and a known positive such as secondary clarifier effluent should be run to ensure test viability.

5.5.6.2 Acceptability Criteria

The sterile dilution water blank should yield no fecal coliform colonies after the incubation period. The known positive should yield high fecal coliform counts which adhere to the blue colony characteristics of fecal coliform.

5.5.6.3 Corrective Actions

If dilutions do not yield between 20 and 60 colonies, dilution should be adjusted appropriately. If known positives do not yield positive results, the MF-C Medium may be the problem. Check the expiration date of the current lot number. If the sterile dilution water blank yield positive results, contamination is being introduced into the test. Verify that sterilization techniques are adequate. Always run the blank prior to running samples and always proceed in the analysis from greater dilutions to the smaller dilutions.

5.5.7 Documentation and Reporting

5.5.7.1 Bench Data

The analyst should record the following information for fecal coliform for each sample analyzed:

1. Sample date and time
2. Sample location or identity
3. Incubation time in and time out
4. Identity of analyst
5. Sample dilution/volume in mls
6. Multiplication factor
7. Colony counts for all dilutions
8. Blank and known positive results
9. Number of colonies per ml for each dilution or sample

5.5.8 Maintenance

All glassware, equipment, sample bottles, etc., must be cleaned and sterilized prior to each test. The autoclave should be serviced by a manufacturer's representative annually.

5.6 LABORATORY RECORDS

The importance of maintaining complete and accurate laboratory records cannot be stressed strongly enough. Laboratory records provide the basis for information contained in regulatory required reports. These records can also indicate the efficiency of the WWTP and its treatment units, and help analyze past and future problems.

Laboratory records should be kept in loose-leaf binders and in journal-type log books in the WWTP laboratory. In addition, bench sheets showing calculations should also be kept in loose-leaf binders. Example bench sheets are included in Appendix A. The following analyses records should be kept to ensure compliance with permit and regulatory requirements.

- D.O. and BOD tests.
- pH tests.
- Suspended solids tests.
- Stream survey tests.
- Dilution water incubation records.
- Composite sample records.
- Lab refrigerator records.
- Drying oven records.
- Temperature reading records.
- BOD incubator records.

The applicable laboratory data are also transferred onto the WWTP daily operating log sheets and Air Force forms 1462 and 1463.

5.7 DATA ANALYSIS

Accurate data are necessary for process optimization of a wastewater treatment plant. Sections 5.2 through 5.6 presented the proper procedures for running the laboratory tests necessary to operate the Howard AFB wastewater treatment plant. Collection of the data is the first step in process optimization. Data handling and analysis is the next step.

A very useful method of handling data is the use of trend charts. Trend charts are graphs on which the raw data generated at a treatment plant is plotted. By plotting results on a graph the operator is provided with a visual aid that can be related to plant performance. This graphic display provides easy access to vital information and, not only presents the past plant performance, but shows current operational status, as well as provides an indication of future performance. Most importantly, it readily relates the results of in-plant adjustments.

The use of trend charts also allows the plant operators to develop an historical data base on which to base future decisions. Many of the problems which can occur in the process control of a treatment plant take months or years to develop. Without the benefit of a long-term data base, it is difficult to identify and correct the problems.

In a wastewater treatment plant any number of parameters can be plotted for trend analysis. A common approach is to plot all permitted parameters in the plant's influent and effluent to assess overall plant operating efficiency. Another approach is to plot process control data such as mixed liquor suspended solids, F/M ratio, sludge retention time and digester percent volatile reduction which can assist the operator in predicting upcoming process upsets.

CHAPTER 6
SAFETY

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SAFETY

6.1 INTRODUCTION

A wastewater treatment plant exposes an operator to many potentially hazardous conditions; however, it need not be an unsafe place to work. Adherence to safety rules and common sense are generally sufficient to protect the operator from injury.

The Howard AFB wastewater treatment plant contains various potential hazards similar to those existing in any wastewater treatment plant. The major types of hazards associated with such a facility are:

1. A potential for occurrence of injuries.
2. Handling of hazardous chemicals.
3. Exposure to various gases at abnormal concentrations.
4. Exposure to infectious diseases.

Due to the presence of these hazards, plant personnel must exercise caution in all their activities around the wastewater treatment plant and must take the steps necessary to protect all visitors to the plant from dangers unknown to them. A good plant safety program and safe working procedures and conditions are the keys to voluntary compliance with the Occupational Safety and Health Act of 1970 (OSHA). This section describes methods for achieving these safety objectives at the Howard AFB Facility. Some of the primary benefits of an effective safety program include lower operating costs, improved treatment efficiency, good employee morale, and positive community relations.

A constant conscious effort must be made both by plant management and by plant personnel to maintain a safe working environment. Every accident, injury, or work-related illness serves as an indication that there is a problem either with plant design, equipment specification or function, standard plant procedures, or employee assignment, capabilities, or training. Ideally, such problems should be recognized and remedied prior to occurrence of any undesirable situations. However, if an accident should occur, the source of the problem should be sought out and remedied immediately.

Howard AFB currently has a very active and detailed safety program for the WWTP. Safety procedures are based on AFOSH Safety Standards. A work place hazard analysis of the WWTP and related job tasks has been performed. From the hazard analysis, specific safety procedures have been developed. Examples of these specific procedures include:

- Safe handling of chlorine cylinders,
- Changing chlorine gas cylinders,
- Working around open tanks,
- Chemical handling, and
- Working around operating mechanical and electrical equipment.

Other hazardous aspects of the Howard AFB WWTP safety program include:

- Provision of appropriate personal protective equipment for plant personnel,
- Inspection procedures for respirators,
- Use of a daily safety checklist for the WWTP, at lift stations and at swimming pool areas,
- Emergency procedures for activities such as fire reporting, personnel evacuation and personnel injury,
- Procedures for operation and maintenance of self contained breathing apparatus and for emergency chlorine leak repair kits.

This section of the O&M Manual is designed to present additional safety related topics and to augment current procedures. Further references in the area of safety for the Howard WWTP can be obtained from the Water Environment Federation. Some pertinent references include:

- SM-2, Guidelines for Developing a Plant Safety Program.
- MOP-1, Safety and Health.

6.2 IMPACT OF REGULATIONS ON SAFETY/GENERAL CONSIDERATIONS

The OSHA regulations, which became law in 1971, were implemented to eliminate unsafe working conditions in American industries. Portions of this law are applicable to wastewater treatment works and cover the activities of both the management and operations personnel.

6.2.1 Management Responsibilities

Plant management is responsible for the development, implementation, and administration of the health and accident prevention program. These duties include, but are not limited to, the following:

1. Provide the leadership necessary to assure and maintain employee interest and participation.
2. Be familiar with job requirements, plant layout, facilities, fire protection systems, and fire prevention needs to the degree that unsafe acts or unsafe conditions can be recognized, discussed, and corrected.
3. Be the focal point for coordination and review of accident investigations and reports.
4. Review and select applicable safety materials for display or distribution.
5. Cooperate and assist with outside agencies that need to inspect, survey, or acquire knowledge of specific operations (Occupational Safety and Health Administration [OSHA] compliance officers, health officials, fire department personnel, Air Force inspectors and so on).
6. Review the safety program periodically and amend it when necessary.
7. Require that employees adhere to safe procedures in the performance of their job.

In addition to the above responsibilities, management must insure that the workplace is free from identifiable hazards which could cause physical injury, disease, or death. Potential hazard points which must be examined include light, noise, walkway clutter, ventilation, defective equipment, hygiene facilities, personnel break areas, and many others.

Management also has the responsibility to provide all applicable protective equipment and tools which are required for the employees to carry out their work assignments. Protective equipment includes eye protection, body protection, and respiratory protection.

Management will also be responsible for providing safety training and instruction. This involves identifying and determining training needs and objectives. Efforts include hands-on and classroom training conducted by in-plant personnel. It also includes training by safety professionals (Red Cross, Fire Department), equipment and chemical suppliers, and other outside sources. Some of these types of programs are currently in place at the Howard WWTP and should be continued. Additional training by equipment and chemical suppliers should also be pursued.

6.2.2 Employee Responsibilities

The regulations outline responsibilities for the employees to follow. As mandated by OSHA, these occupational and safety standards are applicable to the actions of the staff in carrying out the assigned job duties. The employee must be a positive influence on the safety program. Each employee is the person most concerned for his/her safety and must assume certain duties and responsibilities to assure on-the-job safety. These include, at a minimum:

1. Knowing his/her job and applying safe work practices as guided by published plant work rules or procedures.
2. Recognizing the hazards of the job and taking precautions to ensure his/her safety and the safety of those around him/her.
3. Informing his/her supervisor of hazards or unsafe acts and making recommendations as to how to eliminate or minimize those hazards.
4. Actively participating and cooperating in the overall safety program.
5. Maintaining cleanliness at the job station and maintaining good personal health habits.
6. Reporting to work well-rested so that he/she is in a good state of mind, receptive to instructions, and physically capable of doing the job.

6.2.3 Safety Inspections

Regular safety inspections must be performed to ensure that a safe work environment is maintained within the plant. Inspections should be performed monthly. The purpose of the inspection is to detect, identify, and control hazards before accidents occur.

Safety checklists should be developed for specific areas (tanks, pump stations) or items (fire extinguishers, first aid kits, and safety showers). The lists should be simple and brief and should not include unnecessary items. Unsafe conditions encountered during the inspection should be corrected in the most timely and cost-effective manner.

Hazardous conditions should be immediately brought to the attention of the NCOIC. All hazardous areas should be documented on AF Forms 457, USAF Hazard Report.

6.2.4 Accident Investigation and Reporting

All accidents, injuries, and work-related illnesses must be reported immediately to the water and waste supervisor. This will provide compliance with laws and regulations designed to protect both the employer and the employee, as well as insuring that prompt and effective first aid, medical or hospital treatment is given to the employee. Prompt reporting may help to reduce the severity of the injury as well as the amount of time lost off the job. The filing of a complete report serves two primary purposes. It serves as a record of the incident which can be used in settling any claims, and it is used by plant administration in determining what changes should be made to help prevent accidents, injury, or illness. On-the-job injuries should be reported to the Civilian Personnel Officer using Form CA-1. Near accidents should also be reported, as they may indicate an unsafe condition which should be corrected. A critical aspect of any safety program is an effective system for accident investigation, accident reports, report analysis, and corrective action.

6.3 PLANT PROTECTIVE DEVICES

Several structures and devices have been incorporated into the Howard AFB treatment plant design for the express purpose of providing a measure of safety to plant employees. It is imperative that these structures and devices be utilized consistently. The use of preventive measures to avoid accidents is highly preferable to the necessity for responsive measures.

6.3.1 Handrails

Hand railings and hand chains are provided on walkways around and over tanks specifically at the clarifiers, influent wet well, aeration tanks, digesters and chlorination chamber. These serve to protect plant employees from falls during routine operation inspections, particularly when surfaces are slippery. These devices are for the safety of operators and visitors and should not be bypassed by climbing over or cutting. Flotation rings are provided at the headworks structures, secondary clarifiers, aeration basins, and digesters for use in case of personnel falling into the tanks.

6.3.2 Walkways

Caution must be exercised on elevated walkways. Operators should visually check to see if all grates are in place before walking across them.

Anytime a walkway grating is removed for any reason, temporary barriers should be placed around the open area. Brightly colored tape or cloth should also be used to warn and protect the unwary.

6.3.3 Belt and Coupling Guards

All rotating and moving equipment is protected with belt and coupling guards and other safety devices. Guards are installed to keep anyone from accidentally getting clothes, tools, or bodily parts in contact with moving machinery. Guards are also installed to protect employees should a piece of belt, coupling, or other part break loose and be slung out of the machinery. Guards must be periodically checked for proper installation. They must never be removed while the machinery is in operation. Guards must never be left off "temporarily" for convenience reasons. Any missing guard must be replaced as soon as possible.

6.3.4 Safety Signs

Warning signs, properly placed, serve as a reminder to the thoughtless and uninformed. The instructions outlined on all safety warning signs must be strictly obeyed. Care should be taken never to block the view of such signs, and any safety signs which have become illegible should immediately be replaced. Never take for granted that all activities can be performed in any given area. Every worker should read and understand all signs in the area in which he/she is working.

Particularly important are "NO SMOKING" signs, particularly in the area of the anaerobic digesters. In addition, flammable and explosive conditions can exist in some plant structures due to gases given off by the wastewater. "NO SMOKING" signs must be strictly obeyed. "EAR PROTECTION REQUIRED" and "DANGER CHLORINE" signs must also be strictly obeyed.

6.3.5 Fire Extinguishing Equipment

Fire fighting equipment (fire extinguishers) have been placed at strategic locations throughout the Howard AFB wastewater plant. It is imperative that all personnel be familiar with the location and proper use of all fire fighting equipment.

Fire extinguishers are located at the following locations:

- RAS/WAS Pump Station
- Control Building
- Chemical Storage Building
- Bench Stock Storage Area
- Corrall

Regular monthly inspections of this equipment must be made to assure that all units are functional and that all fire extinguishers contain a full charge. Annual inspections should also be performed by an outside contractor. Hydrostatic testing of fire extinguishers should also be conducted regularly, generally at 5-year intervals. In addition to these items, certain fire safety information must be posted throughout the plant, including emergency phone numbers and emergency response instructions.

Fire hazards are always present in areas where lubricants, solvents and fuels are stored. Gasoline and other volatile liquids must be stored in containers made for the purpose. All spills from such materials must be cleaned up immediately and rags, paper, wood, or any other flammable material must not be allowed to accumulate in such storage areas. Fire extinguishers should be provided in all areas where there is electrical equipment or flammable materials.

6.4 PERSONAL PROTECTIVE DEVICES

6.4.1 Hand Protection

Cotton gloves afford protection for general handling of abrasives, sharp objects, and glassware. Where hand protection is desirable but finger dexterity is essential, surgical-type gloves are to be used. Leather work gloves are desirable when manual tasks such as shoveling and raking are necessary.

The operator is cautioned not to wear rings while working in the plant. A ring can catch on machinery or equipment and cause injury to the fingers and hands.

6.4.2 Foot Protection

Safety shoes with built-in steel toe caps must be worn where heavy objects are customarily handled or there are other foot hazards. Rubber-soled safety shoes should be worn where there is a considerable amount of water, acid, or other chemical present on the floors. Safety shoes should also provide ankle protection. Calf-high and hip-high rubber boots may be required when working in flooded areas. Rubber boots should also meet standards of toe, sole, and arch protection.

6.4.3 Body Protection

Laboratory coats, aprons, smocks, coveralls, pants, jackets, hoods, and similar garments need to be used, when indicated, for protection of the body and clothes from corrosive chemicals.

Generally, operations employees should wear long pants and long sleeve shirts. Rain suits can be worn when working in areas where sludge, water, and wastewater may be encountered, as well as for protection from the weather.

6.4.4 Eye Protection

In the wastewater treatment plant, eye protection is necessary when working in the vicinity of operating pumps, performing maintenance, or working under or near piping, valves, and open top tanks where splashing can occur. Some form of protection must always be used in the laboratory when carrying out any operation which contains a possibility of liquid splashing.

Eye protection equipment must provide adequate protection against the particular hazards for which they are designed, and be reasonably comfortable when worn under

designated conditions. Protection equipment should fit snugly and not unduly interfere with the movements of the wearer. They should have adequate durability, and be capable of being disinfected and easily cleaned. Persons requiring corrective lenses should be issued prescription safety eyewear with appropriate side shields. For short periods, they can wear goggles or face shields over their own glasses.

6.4.5 Safety Shower and Eyewash Facilities

At this writing, one safety shower/eyewash facility is located outside the control building to prevent or minimize injuries to personnel from chemicals, clothing fires, and other emergencies in which volumes of water are needed for protecting personnel. All employees should be familiar with the location and use of this equipment. A second eyewash/safety shower is planned for the area of the chlorinator.

The showers and eyewash must be maintained in good working order. Monthly inspections must be conducted to insure the proper operation of the facilities. Additionally, the shower and eyewash must be cleaned periodically to insure cleanliness. Access to the safety shower must always be kept clear in case of an emergency.

6.4.6 Noise Protection

Noise is generated at a wastewater treatment plant due to the large numbers of mechanical equipment required for the treatment processes. Prolonged exposure to excessive noise can cause hearing loss. The loss can be very slow and usually goes unnoticed until it is too late. Hearing loss from noise exposure can be permanent.

Anytime an employee is to be working in an area of excessive noise, personal protection devices must be used. There are a number of devices available including ear plugs and ear-muff type protectors. "EAR PROTECTION REQUIRED" signs must be strictly obeyed.

6.4.7 Respiratory Protection

Collection systems and wastewater treatment plants sometimes contain contaminated atmospheres that are dangerous to the respiratory system. Some of the hazards commonly found are chlorine gas, carbon monoxide gas, paint or solvent fumes, dust, or particulates, hydrogen sulfide gas, and lack of oxygen. There are several kinds or types of respirators available with each one designed for a specific purpose, type of

contaminant concentration, and period of time to be used. For example, respirators range from a simple dust mask to fully self-contained breathing apparatus (SCBA).

Employees must be fully trained on the job in how to wear and use respiratory devices. If respirator usage is only occasional or infrequent, a periodic skill and knowledge test is required. Ideally, this should be done monthly; at a minimum, quarterly. An outside group, such as the fire department, should be utilized to verify and augment this training. All training on SCBAs should be documented in a safety log.

All respiratory protection equipment must be inspected weekly and monthly. The respirators must be cleaned and all parts tested, inspected, and made ready for immediate operation. Procedures for inspection and storage are provided for each SCBA by the manufacturer.

6.4.7.1 Self-Contained Breathing Apparatus

When an employee must enter an atmosphere that is immediately dangerous to life, a self-contained breathing apparatus (SCBA) must be used. Such devices provide complete respiratory protection in all toxic or oxygen deficient atmospheres. This type of respirator includes a high pressure cylinder of air, a cylinder valve, a demand regulator, a facepiece, and tube assembly. To use, the worker adjusts the facepiece, turns on the cylinder valve, and breathes in to draw the air through the demand regulator to the facepiece. The worker must exhale to the surrounding atmosphere through the exhalation valve. This type of unit can generally only be used for 30 to 60 minutes at a time. Two SCBA's are provided at the Howard AFB WWTP. One is for use at the chlorine facility and one for use in outlying locations.

6.4.8 Medical Services and First Aid

The names, locations, and telephone numbers of doctors, hospitals, and emergency response services will be posted in locations of high visibility. These lists should be updated at least annually. All employees must know where these notices are posted.

At least one well-maintained first aid kit must be kept readily available in the Howard AFB Facility. All employees should be trained in the use of the contents of the first aid kits.

Employees should maintain current certification in cardio-pulmonary resuscitation (CPR). Only these persons should attempt to administer cardiac life support. Improperly performed CPR is likely to cause serious damage to ribs and internal organs without sustaining breathing and heart functions.

Emergency numbers for the Howard AFB wastewater treatment plant include:

Hospital/Ambulance/Emergency	-	119
Fire - on base	-	119
Air Police	-	119

6.5 PERSONAL HEALTH

Because of the sometimes cramped quarters and corrosive or dangerous materials found in treatment plants, it is necessary for the operations staff to keep alert to all possible hazards when performing routine or emergency tasks. Also, remember that visitors to the Howard AFB wastewater treatment plant are not as well informed as you are so caution them to keep their hands off plant equipment. Discussed below are several areas of concern.

6.5.1 Hygiene/Bacterial Infection

Wastewater always presents a potential health hazard. Operators should be advised to keep fingers from the nose, mouth, and eyes. A majority of hazardous and/or infectious materials are carried on the hands of workers. Wastewater treatment plant workers can well take note of the slogan commonly used by bacteriologists, "a good bacteriologist never places his hands above his collar while at work." After work and before eating, the hands should be washed thoroughly with plenty of soap and hot water. The nails should be kept short and foreign material be removed with a nail file or stiff soapy brush. When the hands are soiled, smoking pipes, cigarettes, or cigars may introduce hazardous material into the mouth.

Hazardous materials can also be transmitted to the body from contaminated tools and lab equipment. Never use the mouth to draw samples into pipettes as this could easily cause hazardous materials to be introduced into the mouth.

Gloves should be worn to prevent infection while cleaning equipment, handling sludge, taking or handling samples, or handling any tools or equipment within the plant where they can safely be worn. Gloves are particularly important when the hands are chapped or the skin is broken from a wound.

Food and drink must be kept in the Control Building. Never store food in any container or refrigerator where wastewater samples are stored as this poses grave dangers of contamination.

Cuts received while working should receive prompt first aid. All cuts, no matter how minor, should be reported.

6.5.2 First Aid

The importance of first aid kits cannot be overemphasized. All employees must know their locations and understand the use of their contents. Prompt attention to all injuries is important. For all but minor injuries, a doctor should be called. Red Cross courses in first aid afford an excellent opportunity for training. The fire department and/or emergency response service should be contacted immediately whenever emergency reactions involve resuscitation or emergency handling of gas mishaps.

6.6 PLANT HAZARDS AND SAFETY PROCEDURES

The following paragraphs describe hazards which could be present in certain parts of the Howard AFB wastewater treatment plant and recommended methods to reduce those hazards. Risk of injury can be reduced by always remembering to think things through before starting a job.

6.6.1 Fire and Explosion Hazards

It cannot be overemphasized that every wastewater treatment plant operator must obey "No Smoking" signs and should be cautioned as to the danger of smoking, dropping lighted matches, burning tobacco or using open flames in the Howard AFB facility. An igniting spark can even be created in removing manhole covers, and explosions from this have occurred.

Gasoline, solvents, and other non-domestic waste can be found in the wastewater influent. The vapors from these fluids, when mixed with air in the right proportions, can explode violently if ignited. Investigations by the National Bureau of Mines have shown that gasoline and petroleum vapors will be found in the lower portion of manholes or sewers and in greater concentration just above the liquid surface. Due regard must be made for the time of the year, the velocity and direction of the wind and barometric conditions. They have also found that explosions of such vapors are generally extremely destructive.

In any area where explosive or flammable gases may tend to accumulate, such as manholes, or confining structures, an explosimeter should be used to detect such gases prior to entering or working in such areas. Detailed safety considerations for confined spaces are discussed in Section 6.8.

Good housekeeping practices are important to fire prevention. The accumulation of rubbish should be prevented, and all oil-soaked and paint-soaked rags should be placed in covered metal containers. Direct access to all exits, stairs, and fire fighting equipment must be kept clear of any obstructions. All combustible materials must be kept away from heat sources and other ignition sources.

Each operator should be familiar with the location of the fire extinguishers. The plant staff must be trained in the use of fire extinguishers and other fire fighting equipment.

6.6.2 Gases

An ever-present danger in every wastewater treatment plant is the production and collection of noxious and/or harmful gases. These gases may also be flammable or explosive.

The following places at the Howard AFB wastewater plant and collection system are most likely to be dangerous due to such gases:

1. Lift stations.
2. Manholes.
3. Any covered tank.
4. Pump section wells.
5. Headworks.

This list is not all-inclusive. Many other areas of the plant may contain accumulations of harmful, toxic or flammable gases. A partial list of gases commonly found in wastewater treatment plants is provided on Table 6.1.

6.6.2.1 Hydrogen Sulfide

Due to the nature of the wastewater processed at the Howard AFB facility, hazardous gases may be present in various areas of the plant. One of the most prevalent and dangerous gases present at wastewater treatment facilities is hydrogen sulfide (H_2S). Hydrogen sulfide is a flammable, colorless gas that is soluble in water. Hydrogen sulfide is evolved whenever the pH of a wastewater is less than 8.0 and sulfur is present in its reduced form (sulfide). Accumulation of hydrogen sulfide can occur in sewer lines, various sumps and wet wells, and poorly ventilated areas where wastewater or sludge is present.

Acute exposure may cause immediate coma which may occur with or without convulsions. DEATH MAY RESULT with extreme rapidity from respiratory failure. The toxic action of hydrogen sulfide is thought to be due to its binding of the iron which is essential for cellular respiration.

Subacute exposure results in headache, dizziness, staggering gait, excitement suggestive of neurological damage, and nausea and diarrhea suggestive of gastritis. Fortunately, recovery from subacute exposure is usually complete.

In areas where exposure to hydrogen sulfide exceeds 10 ppm, workers should wear fullface canister gas masks or air respirators. Because hydrogen sulfide is a flammable gas, workers must shut off ignition sources and use non-igniting/sparking equipment in the presence of hydrogen sulfide.

First aid for exposure to hydrogen sulfide is to call for medical aid, move victim to fresh air, give artificial respiration if breathing has stopped or oxygen if breathing is difficult. If eyes have been exposed to hydrogen sulfide, they should be flushed with plenty of water.

Table 6.1

Characteristics of gases common to the wastewater industry.

Gas and chemical formula	Specific gravity	Explosive limits LEL	Explosive limits UEL	Max. safe 60-min. exposure (% vol. in air)	Max. safe 8-hr exposure (% by vol. in air)	Common properties	Physiological effects	Location of highest concentration	Most common sources	Simplest and safest method of testing
Ammonia NH_3	0.59	16	25	0.03	0.01	Colorless, sharp, and pungent	Irritates eyes and respiratory tract; toxic at 0.01%	Up high	Sewer gas	Oxygen deficiency indicator; odor
Carbon Dioxide CO_2	1.53	Non-flammable		4.0-6.0	0.5	Colorless, odorless, nonflammable; may cause acid taste in large quantities	Acts on respiratory nerves; 10% cannot be endured for more than a few minutes	Down low but may rise if heated	Sludge, sewer gas, combustion carbon and its compounds	Oxygen deficiency indicator
Carbon Monoxide CO	0.97	12.5	74.2	4.0	0.005	Colorless, odorless, tasteless, non-irritating; flammable, explosive, poisonous	Combines with hemoglobin of blood causing oxygen starvation; fatal in 1 hr. at 0.1%; unconsciusness in 30 min. at 0.25% and causes headaches in a few hours at 0.02%	Up high specifically if in presence of illuminating gas	Manufactured fuel gas, flue gas, combustion and fires	CO indicator
Chlorine Cl_2	2.49	Non-flammable		0.0004	0.0001	Yellow, green color; irritating, pungent odor; nonflammable and supports combustion	Irritates respiratory tract, causes irritation and burning of the skin, coughing, and pulmonary edema in small concentrations	Down low	Chlorine cylinder and feed line leaks	Chlorine detector
Ethane C_2H_6	1.05	3.1	15	No limit provided oxygen percentage (at least 12%) is sufficient for life		Colorless, odorless, tasteless, flammable, explosive, non-poisonous	Acts mechanically to deprive tissues of oxygen; does not support life	Down low	Natural gas	Combustibde gas indicator, Oxygen deficiency indicator

Table 6.1--Continued

Gasoline **C_5H_{12}—C_9H_{20}**	3.0-4.0	1.3	7	0.4-0.7	**Varies**	Color, flammable, explosive, odor noticeable at 0.03% concentration	Symptoms of intoxication when inhaled, difficult breathing and convulsions; fatal at 2.43%	Down low	Service stations, storage tanks and dry cleaning operations	Combustible gas indicator; oxygen deficiency indicator
Hydrogen Sulfide **H_2S**	1.19	4.3	46	0.02-0.03	0.001	Rotten egg odor in small concentrations; colorless, flammable, and explosive	Paralyzes the respiratory system; lessens the sense of smell as concentration increases; rapidly fatal at 0.2%	Down low; can be higher if air is hot and humid	Coal gas, petroleum, sewer gas and sludge gas	Lead acetate paper, lead acetate ampoules, H_2S detector
Methane **CH_4**	0.55	5	15	No limit providing sufficient oxygen (at least 12%) is present		Colorless, odorless, tasteless, explosive, flammable, and non-poisonous	Deprives tissues of oxygen; does not support life	At top, increasing to certain depth	Digestion of sludge	Combustible gas indicator; oxygen deficiency indicator
Nitrogen **N_2**	0.97	Non-flammable		—	—	Colorless, tasteless, odorless, and non-fammable	In very high concentrations, reduces oxygen intake; does not support life	Up high and sometimes in low areas	Sewer and sludge gas	Oxygen deficiency indicator
Oxygen (in air) **O_2**	1.11	Non-flammable		—	—	Colorless, odorless, tasteless; supports combustion	Normal air contains 20.93% O_2. Below 19% considered deficient; 13% dangerous; below 5%-7% fatal	Variable at different levels	Oxygen deficiency from poor ventilation and chemical combustion of O_2	Oxygen deficiency indicator
Sludge gas	varies	5.3	19.3	Varies with composition		Flammable, practically odorless, and colorless	Will not support life	Up high	Digestion of sludge	Combustible gas indicator, oxygen deficiency indicator

6.7 ELECTRICAL MAINTENANCE SAFETY

Nearly all the equipment within the Howard AFB Facility is operated by electricity. Maintenance and day-to-day activities require personnel to handle and control this equipment. Unless safe work practices are strictly observed, serious injury or death can result.

Ordinary 120 V electricity may be fatal. Extensive studies have shown that currents as low as 10 to 15 mA can cause loss of muscle control and that 12 V may, on good contact, cause injury. Therefore, all voltages should be considered dangerous. Most electrical systems at wastewater treatment plants operate at voltages from 120 to 4000 or more. All electricity should be treated cautiously and without guessing as to the nature of the electrical circuit.

Electricity kills by paralyzing the nervous system and stopping muscular action. Frequently, electricity may hit the breathing center at the base of the brain and interrupt the transmission of the nervous impulses to the muscles responsible for breathing. In other cases, the electrical current directly affects the heart, causing it to cease pumping blood. Death follows from lack of oxygen in the body. It cannot be determined which action has taken place; therefore, a victim must be freed from the live conductor promptly by use of a dry stick or other nonconductor, or by turning off the electricity to at least this point of contact. Never use bare hands to remove a live wire from a victim or a victim from an electrical source. Next, cardio-pulmonary resuscitation or artificial respiration should be applied immediately and continuously until breathing is restored, or until a doctor or emergency medical technician arrives.

6.7.1 General Electrical Safety Rules

1. As long as you are not grounded, that is, as long as current cannot pass through your body to the ground, you are safe. While working on electrical circuits, do not touch the switch box cabinet or any other object, such as a pipe, that will give electric current a path through your body. Do not stand in water and, if possible, place a rubber mat under your feet.
2. Allow only authorized people to work on electrical panels.
3. Keep rubber mats on the floor in front of electrical panels.
4. Treat all electrical wires and circuits as "live," unless certain they are not.

5. Never work alone on energized equipment that operates at or above 480 V. When two employees work together, one can double-check the other, and there is always one employee available to de-energize circuits, apply first aid, or summon assistance in the event of a mishap.
6. Use approved rubber gloves.
7. Electrical control panels should never be opened unless the job requires it.
8. No part of the body should be used to test a circuit.
9. Always work from a firm base as loss of balance may cause a fall onto energized busses or parts. Electrical parts should be covered with a good electrical insulator such as a rubber blanket.
10. No safety device should be made inoperative by removing guards, using oversized fuses, or blocking or bypassing protective devices, unless it is absolutely essential to the repair or maintenance activity, and then only after alerting operating personnel and the maintenance supervisor.
11. All tools should have insulated handles, be electrically grounded, or double insulated.
12. Jewelry should never be worn when working on electric circuits.
13. Use fuse pullers to change fuses.
14. Never use metal ladders, metal tape measures, or other metal tools around electrical equipment.
15. Keep wires from becoming a tripping hazard.
16. When performing electrical work, even simply energizing a piece of equipment, observe "No Smoking" signs.
17. When working around electrical equipment, keep your mind on the potential hazards at all times.

6.7.2 Holding and Locking Out Electrical Circuits

The most important safety requirement in electrical maintenance is to have and adhere to a good system for holding and locking out electrical circuits when equipment is being repaired. Unexpected operation of electrical equipment that can be started by

automatic or manual remote control may cause injuries to persons who happen to be close enough to be struck.

When motors or electrical equipment require repair, the circuit should be opened at the switch box, and the switch should be padlocked in the "OFF" position and tagged with a description of the work being done, the name of the person, and the department involved.

All personnel involved in maintenance work should be instructed in the following lock out procedure:

1. Alert the proper personnel; supervisor, affected operations staff.
2. Before starting work on an engine or motor line shaft or other power transmission equipment, or power-driven machine, make sure it cannot be set in motion without your permission.
3. Place your own padlock on the control switch, lever, or valve, even though someone has locked the control before you--you will not be protected unless you put your own padlock on it.
4. When through working at the end of your shift, remove your padlock or your sign and blocking, never permit someone else to remove it for you, and be sure you are not exposing another person to danger by removing your padlock or sign.
5. If you lose the key to your padlock, report the loss immediately to your supervisor and get a new padlock.
6. After repair, clear personnel from area BEFORE closing the breaker.

6.7.3 Explosion-proof Equipment

Before breaking the seal on an explosion-proof enclosure, make certain that the work area has good ventilation. A combustible vapor check should be made. Nearby equipment and facilities should be shut down if practical. The area should be continually monitored for vapors, and only non-sparking, nonferrous tools should be used. On completion of the work, make certain that the explosion-proof fittings have been adequately resealed.

6.7.4 Fire Extinguishers

At all motor control centers, transformer banks, and switchgear installations, fire extinguishers rated "Class C" for use on fires at electrical equipment should be mounted in the immediate vicinity. Water or other conductive liquids and materials that heat should never be used on electrical fires.

6.8 CONFINED SPACE SAFETY

A large percentage of the fatal accidents that have occurred in wastewater treatment plants have occurred in confined spaces. Clearly the problem is a lack of knowledge of the dangers involved in entering and working in confined spaces and the proper procedures to follow to prevent accidents.

6.8.1 Definition of Confined Space

A "confined space" is defined as any enclosed or semi-enclosed space that has restricted means for entry and exit and is not intended for continuous occupancy. Typical confined spaces in the wastewater industry are manholes, metering stations, valve or siphon chambers, digestors, silos, empty tanks, pits or any other area in the system that has direct contact with wastewater, sludge, sludge gas, or conduits carrying these substances.

6.8.2 Classification of Confined Spaces

Confined spaces are classified based upon existing or potential hazards. The two classifications of confined spaces are non-permit confined space and permit-required confined space. A non-permit confined space does not contain atmospheric hazards or have the potential to contain any hazard capable of causing death or serious physical harm. Examples of non-permit confined spaces include vented vaults or motor control cabinets. These spaces have either natural or permanent mechanical ventilation to prevent the accumulation of a hazardous atmosphere, and they do not present engulfment or other serious hazards. A permit-required space has one or more of the following characteristics:

- Contains or has the potential to contain a hazardous atmosphere
- Contains a material that has the potential for engulfing a person
- Has an internal configuration such that a person could be trapped by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section
- Contains any other recognized serious safety or health hazard

The plant safety representative shall evaluate the workplace to determine if any spaces are permit-required confined spaces. Procedures described in paragraphs 6.8.3 through 6.8.10 apply only to permit-required spaces. Since non-permit spaces are free of

atmospheric or safety hazards they do not require special entry protocols. If there are changes in the use or configuration of a non-permit confined space that could increase the hazards to the entrants, the plant safety representative shall reevaluate the space and reclassify it as a permit-required space if necessary.

6.8.3 Warning Signs

A plant that contains permit-required confined spaces must post warning signs at the entrance to these spaces. Signs must as a minimum contain the following language:

DANGER PERMIT-REQUIRED CONFINED SPACE DO NOT ENTER

6.8.4 Permit-Required Confined Space Entry Permit System

Employees must enter permit-required spaces in accordance with the plant's written permit-required confined space entry program. The written program shall be developed by the plant safety representative or designee and must address the following items:

- Measures necessary to prevent unauthorized entry into confined spaces
- Methods for identifying and evaluating the hazards of the confined space prior to entry
- Procedures and practices necessary for safe entry
- Safety equipment necessary to conduct operations
- Methods to evaluate space conditions during entry operations
- Designated persons who are to have active roles in confined space operations (for example, entrants, attendants, and entry supervisor) and their duties
- Methods to apprise contractors of precautions or procedures to implement when hired to conduct operations in a permit space

6.8.5 Entry Permit

Entry into any area designated as a permit-required confined space will require a permit. The permit is an authorization and approval in writing that specifies the location and type of work to be done, and certifies that all existing hazards have been evaluated and necessary protective measures have been taken to ensure the safety of each worker. The entry permit must address the following items:

- The permit space to be entered
- The purpose of the entry
- The date and the authorized duration of the entry permit
- Names of the persons who will enter the confined space (entrants)
- Names of the persons who will be attendants
- The name of the entry supervisor
- The hazards of the confined space to be entered
- The measures used to isolate the permit space and to eliminate or control the hazards before entry into the confined space
- Acceptable entry conditions
- The results of initial and periodic tests accompanied by the names or initial of the tester
- The rescue and emergency services and the means used for summoning the service
- The communication procedures used by entrants and attendants to maintain contact during the entry
- Equipment, such as personal protective equipment, testing equipment, communications equipment, alarm systems, and rescue equipment
- Other information necessary to ensure employee safety, given the circumstances of the particular confined space.

Once the entry has been completed the plant safety representative will cancel the permit. Canceled permits must be maintained by the plant for at least one year. An example of a confined-space entry permit is included at the end of this section.

6.8.6 Equipment for Permit-Required Entry

The following is a list of equipment that must be considered prior to entering and working in permit spaces:

- Ventilation equipment needed to obtain acceptable airborne concentrations
- Atmospheric-testing equipment to identify oxygen deficiency, combustible gases, and suspected toxic gases (e.g., hydrogen sulfide)
- Communication equipment for entrants and attendant
- Personal protective equipment (e.g., respirators, hard hats) insofar as feasible engineering controls or work practices do not adequately protect employees
- Lighting equipment to enable employees to work safely and exit quickly in the event of an emergency
- Pedestrian or vehicle barriers (e.g., traffic cones, barricades, warning signs, traffic flags) to protect entrants from external hazards
- Ladders for safe entry and egress
- Any other equipment necessary for the entry into and rescue from the confined space

6.8.7 Atmospheric Testing of Permit-Required Confined Spaces

All permit-required confined spaces must be considered dangerous before entry until proven safe. Air monitoring shall be performed before removing the cover, if practical. Some lids have openings through which a probe may be inserted. If not, the lid must be carefully removed using appropriate tools, and the atmosphere shall be tested before entry.

The principal atmospheric tests will be for oxygen deficiency and explosive and toxic gases. Combination meters are available that will give an indication of the percentage of oxygen and the percent of the lower explosive limit of the tested atmosphere. Additionally, the atmosphere shall be tested for toxic gases such as hydrogen sulfide, carbon monoxide, methane, carbon dioxide, or other suspected gases or vapors.

It is important to understand that some gases or vapors are heavier than air and will settle to the bottom of a the space, whereas some gases are lighter than air and will be found around the top of the confined space as shown in Figure 6.1.

Test all areas (top, middle, bottom) of a space. Entry will be allowed only when the following atmospheric conditions are met:.

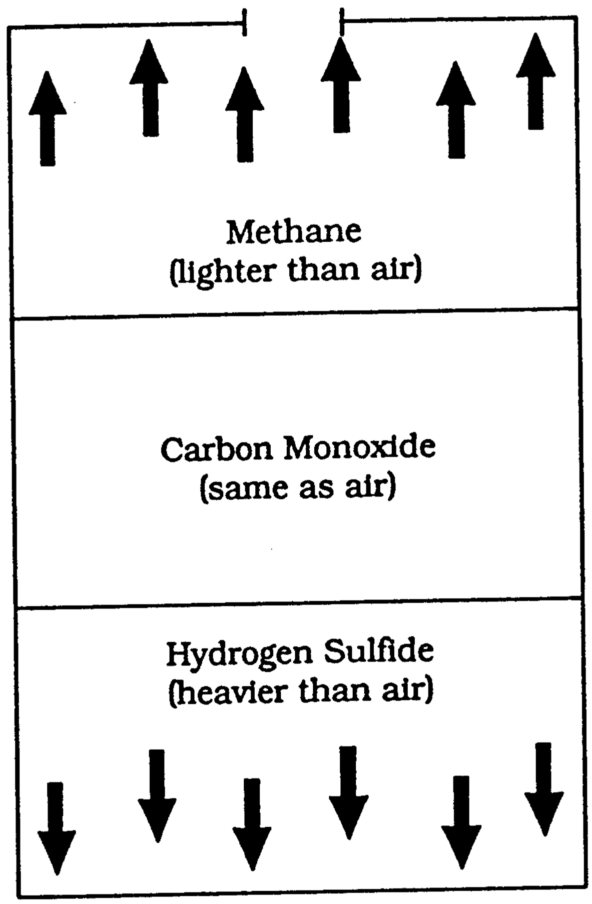
- The oxygen concentration in the confined space is greater than 19.5 percent and less than 23.5 percent by volume.
- The presence of flammable gases or vapors is less than 10 percent of the lower flammable limit.
- Potential toxic gases or vapor are present at concentrations below the OSHA permissible exposure limit (e.g., less than 10 ppm for hydrogen sulfide).

If atmospheric readings do not comply with acceptable entry parameters then ventilation of the space is required. A blower for positive displacement of the atmosphere is often used. Allow sufficient time for the blower to displace three times the volume of the space. Next, retest the space to verify that acceptable concentrations have been met before any entry to the space is made. The blower shall remain in operation throughout occupancy of the space.

When using gasoline- or diesel-powered blowers, ensure that the exhaust gas from the engine is not drawn into the space by the blower. If a hazardous atmosphere persists in spite of ventilation, it will be necessary for the employee to use proper respiratory protection equipment. A positive-pressure self-contained breathing apparatus or positive-pressure airline respirator with a five-minute escape tank is frequently used.

Personnel working in a permit-confined space must be equipped with a continuous atmospheric monitoring device. This is true even if the atmosphere was found to be safe initially since conditions can change. Equipment used for continuous monitoring of the atmosphere shall be explosion-proof and equipped with an audible alarm that will alert employees a hazardous condition develops.

An employee's well-being depends on the proper functioning of safety equipment. Careful, regular maintenance of the monitoring equipment is essential. All monitoring instruments must be calibrated prior to use and, records of calibration maintained. The



Atmospheric Testing: From the Outside, Top to Bottom

limitations and possible sources of error for each instrument must be understood by the operator.

6.8.8 Isolating the Permit Space

Whenever entry into a permit-confined space is necessary, the space must be isolated from all other systems. This is to insure that injury does not occur.

Blanks must be used to physically isolate all lines into the confined space. Shut-off valves or pipelines to the space must be locked in the closed position and tagged for identification. Pumps and compressors connected to these pipelines must be locked out and tagged to prevent accidental activation. In continuous systems, where complete isolation is not possible (e.g., sewers), specific written safety procedures should be developed and used.

Electrical isolation of the confined space is necessary to prevent accidental activation of moving parts that would be hazardous to the worker. Circuit breakers or disconnects should be locked out and tagged in the off position with a key-type padlock. The only key is to remain with the person working inside who locked the breaker. If more than one person is inside the space, each person should place his or her own lock on the circuit breaker.

Mechanical isolation of moving parts can be achieved by disconnecting linkages, or removing drive belts or chains. Equipment with moving mechanical parts should also be blocked in such a manner that there can be no accidental rotation. Remember, lives are at stake, and all of these steps are equally important. All lockout and tagout procedures must conform to OSHA standards (see CFR 1910.147).

6.8.9 Responsibilities and Duties of Personnel Conducting Permit-Required Confined Space Operations

As stated in paragraph 6.8.4, the plant's permit-required confined space entry program should designate personnel who have active roles in the program. Every permit-required confined space operation requires authorized entrant(s), an attendant, an entry supervisor, and access to rescue services.

Any person entering a permit-required confined space must know the potential hazards including the signs or symptoms and consequences of exposure and the required

safety procedures. Entrants must be familiar with the proper use of equipment and should be in constant communication with the outside attendant. When an entrant recognizes signs or symptoms of exposure to hazardous substance or detects a prohibited condition, the entrant must inform the attendant of the problem and initiate evacuation.

The attendant remains outside the permit space during the entire operation and is responsible for maintaining an accurate count of entrants in the confined space. The attendant should communicate with entrants as necessary to monitor status. Similarly to entrants, the attendant must know potential hazards during entry including signs, symptoms, and behavioral effects of exposure to hazardous substances. The attendant monitors activities inside and outside the space to determine if it is safe for the entrants to remain. The attendant is required to order an immediate evacuation of the space when one of the following conditions occur:

- A prohibited condition is detected in the space.
- The attendant detects the behavioral effects of hazard exposure in an entrant.
- The attendant detects a situation outside the space that could endanger the entrants.

In the event of an emergency requiring the rescue of an entrant, the attendant is only permitted to perform only non-entry rescue (i.e., extracting personnel by use of retrieval systems) or to summon rescue services.

The entry supervisor is the individual responsible for the development of the permit and has overall accountability for the safety of the operation. The entry supervisor checks permit entries verifying that all tests specified have been conducted and that all procedures and equipment are in place prior to entry. Additionally, the entry supervisor ensures rescue services is readily accessible.

The nature of work in confined spaces makes emergencies a continual possibility, no matter how infrequently they actually occur. Emergencies occur quickly and unexpectantly and require immediate response. In an emergency, rescue personnel would either enter a permit space to remove entrants or would remain outside and pull out entrants by use of retrieval lines. The plant may either establish an in-house rescue team or make arrangements for off-site services (i.e., fire department). If off-site

emergency rescue services are to be used, the response time to the site must be within four minutes.

6.8.10 Training for Permit-Required Confined Space Work

Anyone entering a permit space must recognize and understand the potential hazards to health and safety associated with the operation. Personnel involved in permit space activities must be thoroughly familiar with the plant's permit-required confined space program and must receive training. The objectives of the confined space training program are:

- To make workers aware of the potential hazards they may encounter
- To provide the knowledge and skills necessary to perform the work with minimal risk to worker health and safety
- To ensure that workers can safely avoid or escape from emergencies

The level of training should be consistent with the worker's job function and responsibilities. The training program must involve both classroom instruction and hands-on practice. Hands-on instruction should consist of entry and rescue drills. Employees must demonstrate proficiency in the knowledge and skills necessary for safe entry and response (proficiency may be demonstrated through oral or written examination or evaluation of field simulations).

Training is required before the employee is assigned to a confined space operation and when the employee's assigned duties change (e.g., when responsibilities change from entrant to attendant). Members of the in-house rescue team must practice confined space rescues annually. This training should consist of simulated rescues in which the team removes a mannequin or people from actual permit-required spaces.

CHAPTER 7
MAINTENANCE

CHAPTER 7
MAINTENANCE

7.1 INTRODUCTION

The term maintenance has many definitions, but in an engineering sense, total maintenance may be defined as the art of keeping plant equipment, structures, and other related facilities in a suitable condition to perform the services for which they were intended. Preventive maintenance is defined as the activities required to prevent process shutdown, reduce the wear on all equipment, and extend the life of equipment and structures. Corrective maintenance is defined as the activities required to repair malfunctioning or inoperable equipment.

To ensure the continuous trouble-free operation of the Howard AFB wastewater treatment plant, an effective "total maintenance" program is required. A "total maintenance" program is a schedule that incorporates preventive maintenance and corrective maintenance activities. By regular inspection and maintenance of each piece of equipment and keeping accurate records of performed maintenance, problems can be anticipated and usually avoided, thus reducing events of equipment failure and unscheduled shutdowns.

Planning and implementing an effective preventive maintenance program are essential in producing quality effluent on a continuous basis. In this chapter, a recommended approach to plant maintenance is discussed in general terms. A preventive maintenance and lubrication schedule for servicing of the plant's equipment is provided. The schedule was compiled from equipment manufacturers manuals and existing WWTP maintenance procedures. Frequency and type of required maintenance reflect these information sources. A manual record-keeping system for maintenance is also described. Forms for this record-keeping system are provided in Appendix B.

7.2 PREVENTIVE MAINTENANCE

Preventive maintenance may be defined as the art of preventing equipment failure by establishing a system of regular inspections and scheduled maintenance based on equipment repair history to detect trouble spots before they become the cause of major problems. Preventive maintenance is the key element in the plan for management of the maintenance function.

Typically, a preventive maintenance (PM) program includes the following:

1. Equipment inspection.
2. Lubrication.
3. Minor adjustments.
4. Housekeeping, keeping equipment clean.
5. Equipment rotation.
6. Record keeping and scheduling.

The following cites just a few advantages of an effective PM program:

1. Fewer Failures. A timely PM program uncovers problems before they become serious enough to cause equipment failure. As a result, routine adjustments and minor repairs take the place of failures.
2. More Planned Work. The timeliness of PM inspections uncovers those major jobs that require preplanning.
3. Fewer Emergencies. An effective PM program has every employee on the alert for those things that cause problems. As a result, fewer problems escape detection to generate an emergency situation.
4. Reduced Overtime. One of the largest contributing factors to overtime is the need to perform emergency repairs.
5. Extended Equipment Life. PM means timely adjustments, better lubrication, etc. Equipment treated in such a way rewards its users by lasting longer and, thus, is less costly to the system users.

7.2.1 Equipment Inspection

The most critical part of the PM program is the "Operations and Maintenance Routine Check." This is the portion of the program that generates the advance information on the status of the equipment. This information provides the lead time that permits maintenance to be planned. The PM program then becomes "detection oriented" with the principal aim of uncovering problems before they become serious. Checksheets for the Howard WWTP are included in Chapter 8 as part of the Standard Operations Procedures.

In the interest of making the best use of time and due to the fact that these two functions are inseparable, "operating conditions" and "maintenance conditions" are examined at the same time. Every item on a plant check list should be examined at least at the frequency indicated. It is good operating procedure to conduct this inspection at the beginning of a shift. Deficiencies found should be noted on a special "Trouble Report" or other approved form for requesting maintenance.

7.2.2 Lubrication

Proper lubrication is essential to keeping treatment plant equipment operating. Lubricants are applied in a number of ways ranging from a hand operated oil can to complicated automated systems. The success of any lubrication system is dependent upon the lubricator's attention to oil levels, applying the proper lubricant in the proper amount at the proper time and on regular inspection of lubrication systems.

The basic rule of thumb for proper lubrication is that the right lubricant must be applied at the right place, at the right time, and in the right amount.

The proper lubricant is specified by the equipment manufacturer. Refer to the operating manual supplied to be sure you are using the proper lubricant.

7.2.3 Minor Adjustments

An ounce of prevention is worth a pound of cure. Both operation and maintenance people must be constantly on the alert for minor problems and make the necessary repairs before major problems develop. This includes such things as:

1. Excessive leakage on packing.
2. Minor oil leaks.
3. Minor leaks on valves and fittings.
4. Belt adjustments.

Excessive leakage on packing, if not adjusted immediately, will ruin the packing and cause damage to shaft sleeves and shafts (some leakage around water lube packing is necessary). Minor leaks, if not stopped immediately, will soon develop into major leaks and major problems. V-Belts, if not adjusted properly, will cause rapid wear of belts and possible breakdown of equipment. These are the types of items that the operator must be very aware of when making routine checks of the plant.

7.2.4 Housekeeping

Maintenance of a clean, safe, and orderly working environment is essential to efficient and effective plant operations. Plant housekeeping is the responsibility of all plant employees, and must be performed on a continuous basis. Certain housekeeping functions can and should be performed by each employee as part of the normal daily work routine. These include:

1. Replacement of all tools and equipment to their normal storage locations.
2. Removal of trash, rocks, and other debris from work areas and walkways.
3. Proper storage of all cleaning solvents and other small chemical containers.
4. Proper disposal of all dirty or oily rags.
5. Thorough cleaning of an area once work in that area has been completed (may include washdown).
6. Prompt cleanup of all spills.
7. Reporting of any dirty, broken, or nonfunctional equipment.

7.2.5 Tools and Tool Room Control

An important aspect of preventive maintenance, as well as corrective maintenance, is the availability of proper tools to do the job. Tools should be stored in specific locations in the Howard AFB wastewater plant control building. Specialty tools and delicate

instruments should be stored in restricted areas, and use of them should be carefully controlled by the plant superintendent or assistant superintendent.

7.3 PLANT MAINTENANCE PROGRAM

A Base-wide preventive maintenance program (Recurring Work Program) is established and is implemented for the WWTP. A computer list of equipment requiring maintenance, or Recurring Work Program Report (RWPR), is produced weekly. This report provides an equipment identification number, maintenance frequency, description of work, estimated and actual hours necessary to perform the activity, and status of work (see Figure 7.1). The RWPR serves as both a work order, and when the work is completed, a report on the work done. It is sent back to Civil Engineering where the computer record is updated. Items on the RWPR not finished that week will continue to appear on subsequent RWPRs until they are completed. In addition to the RWPR, a maintenance action sheet (MAS) is prepared for each piece of equipment requiring maintenance. The MAS contains a list of activities to be performed, the amount of time allocated per activity, the frequency of the activity and the size of the crew needed (see Figure 7.2).

Figure 7.1 Recurring Work Program Report

Figure 7.2 Maintenance Action Sheet

7.4 MAINTENANCE RECORD KEEPING AND SCHEDULING

This section outlines additional maintenance record keeping to ensure continued efficient operation of the Howard AFB wastewater treatment plant. This maintenance data and recordkeeping are essential to a total maintenance program. These forms which are included in Appendix A can be copied and stored in a loose-leaf binder for easy access and use.

7.4.1 Equipment Data

Data cards should be prepared for each item of equipment in the system. Format examples of data cards for pumps, motors, and other mechanical equipment are presented in Figures A.1, A.2, and A.3. Any convenient indexing system may be used, but it is suggested that all mechanical equipment be filed according to the ID number assigned to each piece of equipment.

Upon completion of all equipment data record forms, they should be filed according to system designation and in alphabetical order. These forms will save many hours in the future and will preserve nameplate data on equipment which is subject to obliteration, abrasion, and painting.

7.4.2 Spare Parts Records

A number of spare parts should always be carried in stock to eliminate or reduce the possibility of an equipment item being out of service for an extended period of time due to a lack of parts. The type and number of spare parts to be maintained should be determined based upon the likelihood of failure, the shelf life of the part, the critical nature of the item, local availability of the part, and the time required to get the part when it is needed, if it is not stocked. The manufacturers' O&M literature contains lists of recommended spare parts.

Figure A.4 is a suggested form to serve as a means of maintaining a record of spare parts as they are placed on order, to record their receipt and issue and to inventory the parts in stock.

7.4.3 Inventory Control

In addition to spare parts records for all plant equipment, a file system should also be used to maintain an inventory of expendable supplies, lubricants, and other miscellaneous items. Figure A.5 presents a sample inventory card to be used for this purpose.

7.5 PREVENTATIVE MAINTENANCE SCHEDULE

This section presents the routine preventive maintenance (PM) and lubrication schedule for the equipment included in the Howard AFB wastewater treatment plant. These schedules were derived from maintenance instructions contained in vendor literature. Equipment manuals should be consulted before performing any preventive or corrective maintenance. Vendor literature is located in the WWTP Control Building bookcase. The PM schedules are presented in Tables 7.1 through 7.19.

7.5.1 Safety Precautions

Before any maintenance or inspection is done on the equipment in the treatment system, it is of utmost important that several basic safety precautions be followed:

a) Notify supervisory personnel of intention.

b) Disconnect power to any applicable equipment, lock it out, and tag it. OSHA requires formal lock out procedures be practiced for mechanical and electrical work on all electrically driven equipment.

c) Put on the proper protective gear for the material expected in the equipment.

d) Check for power at the local hand switch to ensure that power is off and test atmosphere for hazardous vapor levels if entering a confined space.

e) Use tools fitted to the job such as non-sparking for an explosive atmosphere.

f) Do not enter any tank or structure considered a confined space unless all appropriate safety procedures are followed.

g) Relieve the pressure and drain all piping, valves and pumps before disassembly.

h) Immediately clean up spillage from nearby equipment or structures.

i) Reassembly equipment per manufacturer instructions.

j) Clear all personnel from immediate area of work before placing equipment back in service.

TABLE 7.1

Lift Station No. 1
Preventative Maintenance Schedule

Weekly
1. Conduct operational check.
2. Clean pump and motor exterior.
3. Check for corrosion on equipment. Clean, paint, prime as required.
4. Check for leaks on suction, discharge, piping seals, packing gland and valves.
5. Check pump for vibration, noise overheating.
6. Tighten or replace loose, missing or damaged nuts, bolts or screws.
7. Check packing glands and tighten as required.
8. Inspect float assembly for proper operation.
9. Clean up area.
10. Check alignment, clearance and rotation of shaft & coupler.
Monthly
1. Lubricate pump and motor.
2. Check electrical system for loose or frayed wiring, tighten or replace.

TABLE 7.2

Lift Station No. 8
Preventative Maintenance Schedule

Weekly
1. Stop and start fan with local switch.
2. Clean wall mounted fan unit.
3. Conduct operational check.
4. Clean pump and motor exterior.
5. Check for corrosion on equipment. Clean, paint, prime as required.
6. Check for leaks on suction, discharge, piping seals, packing gland and valves.
7. Check pump for vibration, noise overheating.
8. Check alignment, clearance and rotation of shaft & coupler.
9. Tighten or replace loose, missing or damaged nuts, bolts or screws.
10. Check packing glands and tighten as required.
11. Inspect float assembly for proper operation.
12. Clean up area.
Monthly
1. Lubricate pump & motor.
2. Check electrical system for loose or frayed wiring, tighten or replace.

TABLE 7.3

Lift Station No. 49
Preventative Maintenance Schedule

Weekly
1. Conduct operational check.
2. Clean pump and motor exterior.
3. Check for corrosion on equipment. Clean, paint, prime as required.
4. Check for leaks on suction, discharge, piping seals, packing gland and valves.
5. Check pump for vibration, nose overheating.
6. Check alignment, clearance and rotation of shaft & coupler.
7. Tighten or replace loose, missing or damaged nuts, bolts or screws.
8. Check packing glands and tighten as required.
9. Inspect float assembly for proper operation.
10. Clean up area.
Monthly
1. Lubricate pump & motor.
2. Check electrical system for frayed wires. Replace or tighten.

TABLE 7.4

Lift Station No. 225
Preventative Maintenance Schedule

Weekly

1. Conduct operational check.
2. Clean pump and motor exterior.
3. Check for corrosion on equipment. Clean, paint, prime as required.
4. Check for leaks on suction, discharge, piping seals, packing gland and valves.
5. Check pump for vibration, noise overheating.
6. Check alignment, clearance and rotation of shaft & coupler.
7. Tighten or replace loose, missing or damaged nuts, bolts or screws.
8. Check packing glands and tighten as required.
9. Inspect float assembly for proper operation.
10. Clean up area.

Monthly

1. Lubricate pump & motor.
2. Check electrical system for frayed wires. Replace or tighten.

TABLE 7.5

Lift Station No. 718
Preventative Maintenance Schedule

Weekly

1. Stop and start fan with local switch.
2. Clean wall mounted fan unit.
3. Conduct operational check.
4. Clean pump and motor exterior.
5. Check for corrosion on equipment. Clean, paint, prime as required.
6. Check for leaks on suction, discharge, piping seals, packing gland and valves.
7. Check pump for vibration, noise overheating.
8. Check alignment, clearance and rotation of shaft & coupler.
9. Tighten or replace loose, missing or damaged nuts, bolts or screws.
10. Check packing glands and tighten as required.
11. Inspect float assembly for proper operation.
12. Clean up area.

Monthly

1. Lubricate pump & motor.
2. Check electrical system for loose or frayed wiring, tighten or replace.

TABLE 7.6

Lift Station No. 735
Preventative Maintenance Schedule

Weekly

1. Conduct operational check.
2. Clean pump and motor exterior.
3. Check for corrosion on equipment. Clean, paint, prime as required.
4. Check for leaks on suction, discharge, piping seals, packing gland and valves.
5. Check pump for vibration, noise overheating.
6. Tighten or replace loose, missing or damaged nuts, bolts or screws.
7. Check packing glands and tighten as required.
8. Inspect float assembly for proper operation.
9. Clean up area.
10. Check alignment, clearance and rotation of shaft & coupler.

Monthly

1. Lubricate pump and motor.
2. Check electrical system for loose or frayed wiring, tighten or replace.

TABLE 7.7

Lift Station No. 949
Preventative Maintenance Schedule

Weekly
1. Stop and start fan with local switch.
2. Clean wall mounted fan unit.
3. Conduct operational check.
4. Clean pump and motor exterior.
5. Check for corrosion on equipment. Clean, paint, prime as required.
6. Check for leaks on suction, discharge, piping seals, packing gland and valves.
7. Check pump for vibration, noise overheating.
8. Check alignment, clearance and rotation of shaft & coupler.
9. Tighten or replace loose, missing or damaged nuts, bolts or screws.
10. Check packing glands and tighten as required.
11. Inspect float assembly for proper operation.
12. Clean up area.
Monthly
1. Lubricate pump & motor.
2. Check electrical system for loose or frayed wiring, tighten or replace.

TABLE 7.9

Grit Chamber Drive
Preventative Maintenance Schedule

Daily
1. Check normal operation. Check motor and drive for unusual noise vibration and temperature.
Monthly
1. Check oil level in gear box.
Quarterly
1. Change gear box oil.

TABLE 7.10

**Grit Screw/Washer
Preventative Maintenance Schedule**

Daily
1. Check for unusual noise, vibration, and or temperature.
Every 100 Hours
1. Grease all bearings.
Semiannually
1. Change oil in worm gear unit.

TABLE 7.11

Influent Pumps
Preventative Maintenance Schedule

Daily	
1.	Check normal operation. Check for unusual noise, vibration, and temperature.
Weekly	
1.	Clean pump and motor exterior.
2.	Check for corrosion on equipment. Clean, paint, prime as required.
3.	Check for leaks on suction, discharge, piping seals, packing gland and valves.
4.	Check pump for vibration, noise overheating.
5.	Check alignment, clearance and rotation of shaft & coupler.
6.	Tighten or replace loose, missing or damaged nuts, bolts or screws.
7.	Check packing gland, tighten or replace packing as needed.
8.	Inspect float assembly for proper operation and clean sump pit.
9.	Clean up area.
Monthly	
1.	Grease pump bearings using high quality NGLI multi-purpose bearing grease.
2.	Check electrical system for loose and frayed wires. Tighten or replace.

TABLE 7.12

Aeration Blower
Preventative Maintenance Schedule

Daily
1. Check for proper operation.
2. Inspect motor for excessive noise and heat.
3. Clean up area as required.
4. Check for proper ventilation.
5. Stop and start fan with local switch.
6. Check packing gland, tighten or replace packing.
Monthly
1. Check electrical wiring and connections.
2. Lubricate shaft bearing and motor, and coupling.
3. Check for proper alignment of driver and driven.
4. Clean wall mounted fan components.
5. Check electric system for frayed wires. Replace or tighten.
6. Clean up area as required.
7. Change oil in bearing housing & add new oil to holder.

TABLE 7.13

Secondary Clarifiers
Preventative Maintenance Schedule

Daily

1. Observe operation of the secondary clarifier drive units. Look for unusual accumulations and check for usual noises, vibrations, or abnormal operating temperatures of bearings and motors.

2. Observe drive support and gear reducer for looseness. Observe for lubricant leakage.

3. Observe surface scum skimmer. Observe for proper action on scum beach and re-entry into tank.

Monthly

1. Check oil sump lubricant levels in gear reducer, grease bearings, check for condensation and/or metal filings in lubricant. Clean out vent.

Quarterly

1. Grease coupling between motor and reducer.

Semiannually

1. Drain the tank. Hose down and inspect all submerged equipment.

2. Check adjustable brace between truss and center cage.

3. Check scraper arms for:

   a. Missing, broken or badly bent, squeegee.

   b. Clearance between floor and bottom of squeegees.

TABLE 7.13 (Continued)
Secondary Clarifiers
Preventative Maintenance Schedule

Semiannually (Continued)

4. Check surface skimmer counter-weights usually attached to the opposite scapper truss or arm.

5. Check the surface skimmer for proper action on the scum beach and proper scraping along the vertical baffle walls.

6. Check torque overload switches.

7. Check all fastenings at the bridge. Retorque to values recommended by manufacturer.

8. Examine fastenings at expansion point at tank wall.

9. Reestablish elevations of scum baffle, weirs and scum beach. Replace any missing bolts. Check all grouting and water proof sealing.

TABLE 7.14

RAS/WAS Pumps
Preventative Maintenance Schedule

Daily
1. Check normal operation. Check for unusual noise, vibration and or temperature.
Every 150 Hours
1. Inspect packing box for excess leakage. Adjust gland and replace packing as necessary.
Every 4000 Hours
1. Replace or clean mechanical seal filter.
Annually
1. Check pump for proper alignment.
2. Check pump for change in vibration.
Every 2000 Hours or Annually
10. Lubricate pump bearings ususing NLGI No. 2 lithium base multipurpose grease.

TABLE 7.15

**RAS/WAS Variable Frequency Drives
Preventative Maintenance Schedule**

Daily
1. Check for unusual noise, vibration and or temperature.
Every 2500 Hours or Semiannually
1. Change oil in unit.
Semiannually
1. Grease bearings.
2. Lubricate handwheel linkage.

TABLE 7.16

Chlorinator
Preventative Maintenance Schedule

Daily

1. Check operation of chlorinator at least once per shift. Check for unusual noises, vibrations and leaking valves and connections. Follow all safety procedures.
2. Clean rotometer as required. Refer to cleaning procedure provided in the manufacturer's equipment manual. When cleaning rotometer, also clean V-notch plug. Follow all safety procedures.

Every 3 Months

1. Conduct a performance check on all elements of chlorinator system as defined in the equipment manual. Follow all safety precautions.

Every 6 Months

1. Clean injector throat and tailway. Follow procedures in the equipment manual. Follow all safety procedures.

Annually

1. Lubricate the motor shaft bearing on the electric positioner with 2 to 3 drops of SAE 10 non-detergent oil.

Every 2 Years

1. Disassemble, clean and reassemble the principal components of the chlorinator system, including the control unit (and injector), plastic tubing, corporation cock and solution tube. Preventive maintenance kits are available from the vendor.

Note: Due to the hazardous nature of chlorine, servicing of the chlorinator should be restricted to trained, authorized personnel who are completely familiar with the entire contents of the instruction book.

TABLE 7.17

Aeration Tanks
Preventative Maintenance Schedule

Annually
1. Drain and clean tanks checking for cracks, leaks, deterioration and drain valves conditions.
2. Check air diffusers for rust, corrosion, and restrictions.

TABLE 7.18

**Digester
Preventative Maintenance Schedule**

Annually
1. Drain and clean tanks checking for cracks, leaks, deterioration and drain valves conditions.
2. Check air diffusers for rust, corrosion, and restrictions.

TABLE 7.19

Chlorine Contact Tank
Preventative Maintenance Schedule

Annually
1. Drain and clean tanks checking for cracks, leaks, deterioration and drain valves conditions.

CHAPTER 8
STANDARD OPERATING PROCEDURES

CHAPTER 8
STANDARD OPERATING PROCEDURES

8.1 INTRODUCTION

This chapter presents standard operating procedures (SOPs) for the Howard AFB wastewater treatment plant. The procedures are presented in a tabular and checklist format so they can be removed, copied and used in the field during operations.

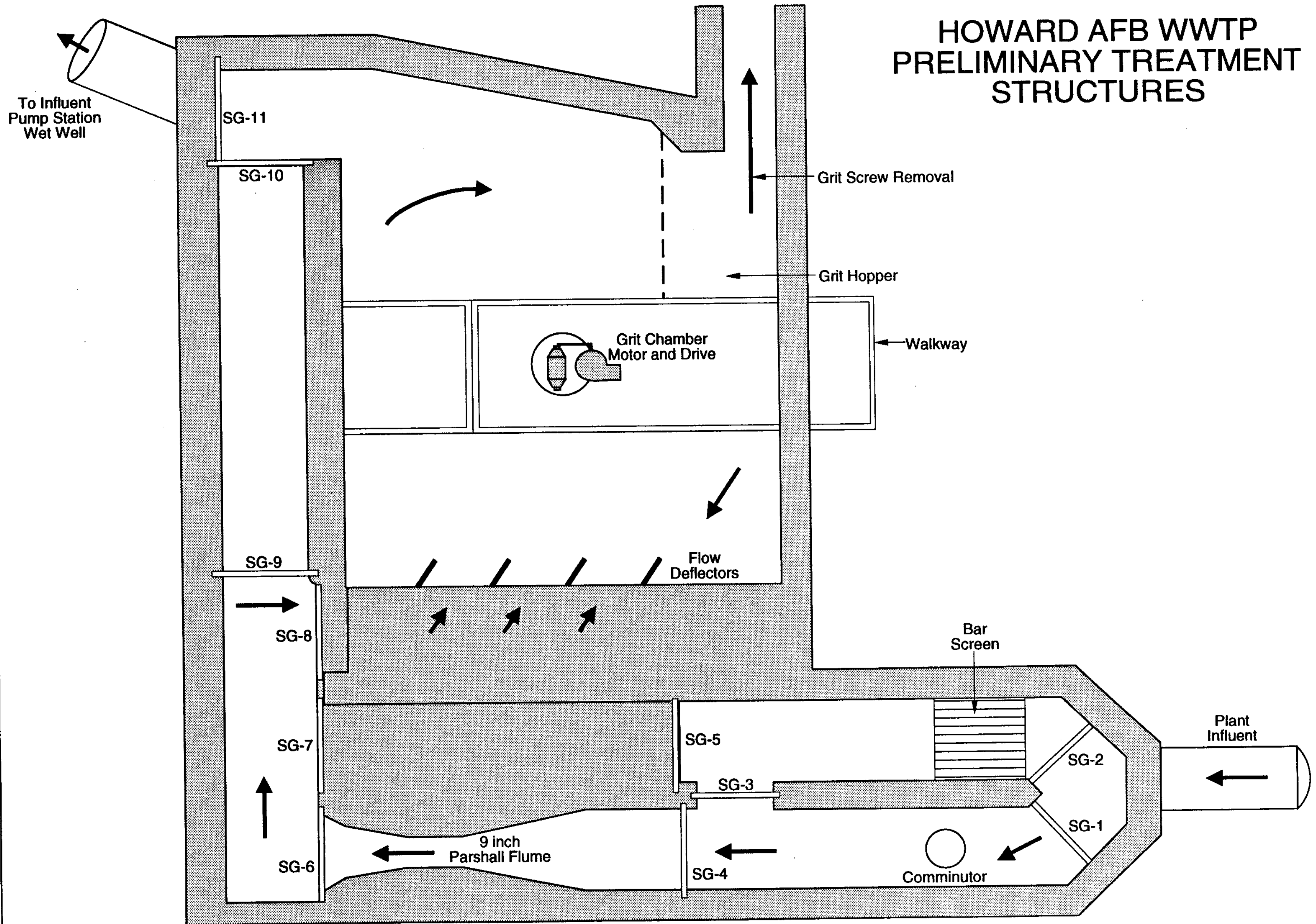
The procedures should be read and understood before initiating operations of the various treatment systems. Also, the daily Operations Log should be utilized for routine plant monitoring. An example Operations Log is provided in Appendix C. Vendor and manufacturer's literature should also be consulted as supplements to these procedures. Additionally, the preventive maintenance and laboratory sampling and analytical schedules contained in Chapters 7 and 4, respectively, should be consulted as needed. These SOPs are designed to aid the operator in the consistent and safe operation of the Howard WWTP. They also can serve as documents to use in training new operators.

No operating procedures can be fully accurate without the input of the operating staff. Thus, when reviewing or using these procedures, the operations personnel should note any conflicts, discrepancies or possible unsafe situations which are inherent in them. Corrections can be then instituted to insure that the procedures accurately describe the proper operating steps.

Figures 8.1 through 8.7 are provided to illustrate valve and gate locations for reference when using these procedures.

Figure 8.1

HOWARD AFB WWTP PRELIMINARY TREATMENT STRUCTURES



G/721012/DG-[illegible]94

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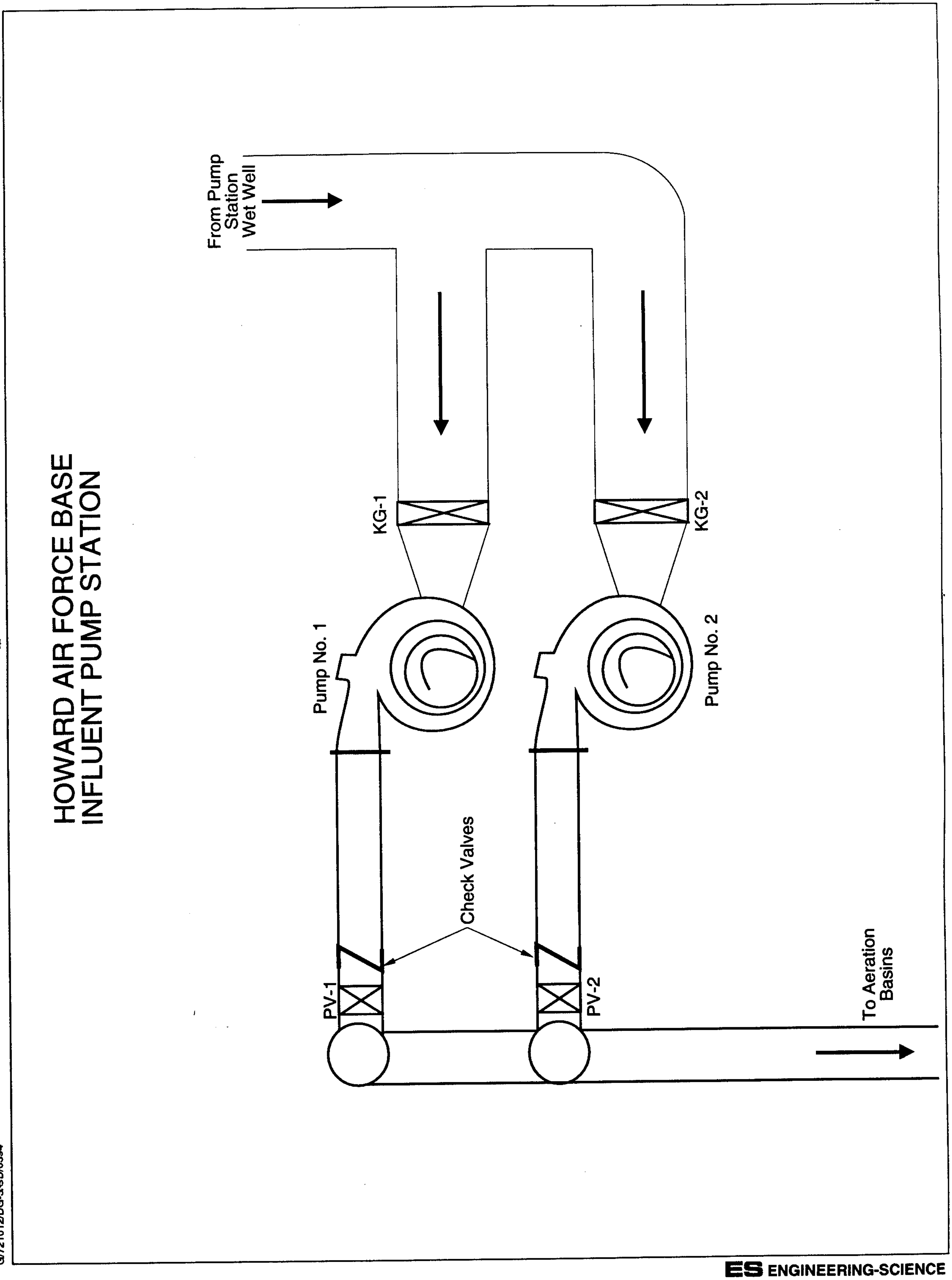
HOWARD AIR FORCE BASE
INFLUENT PUMP STATION
From Pump Station Wet Well
KG-1
KG-2
Pump No. 1
Pump No. 2
Check Valves
PV-1
PV-2
To Aeration Basins

Figure 8.3

HOWARD AIR FORCE BASE
AERATION BASINS

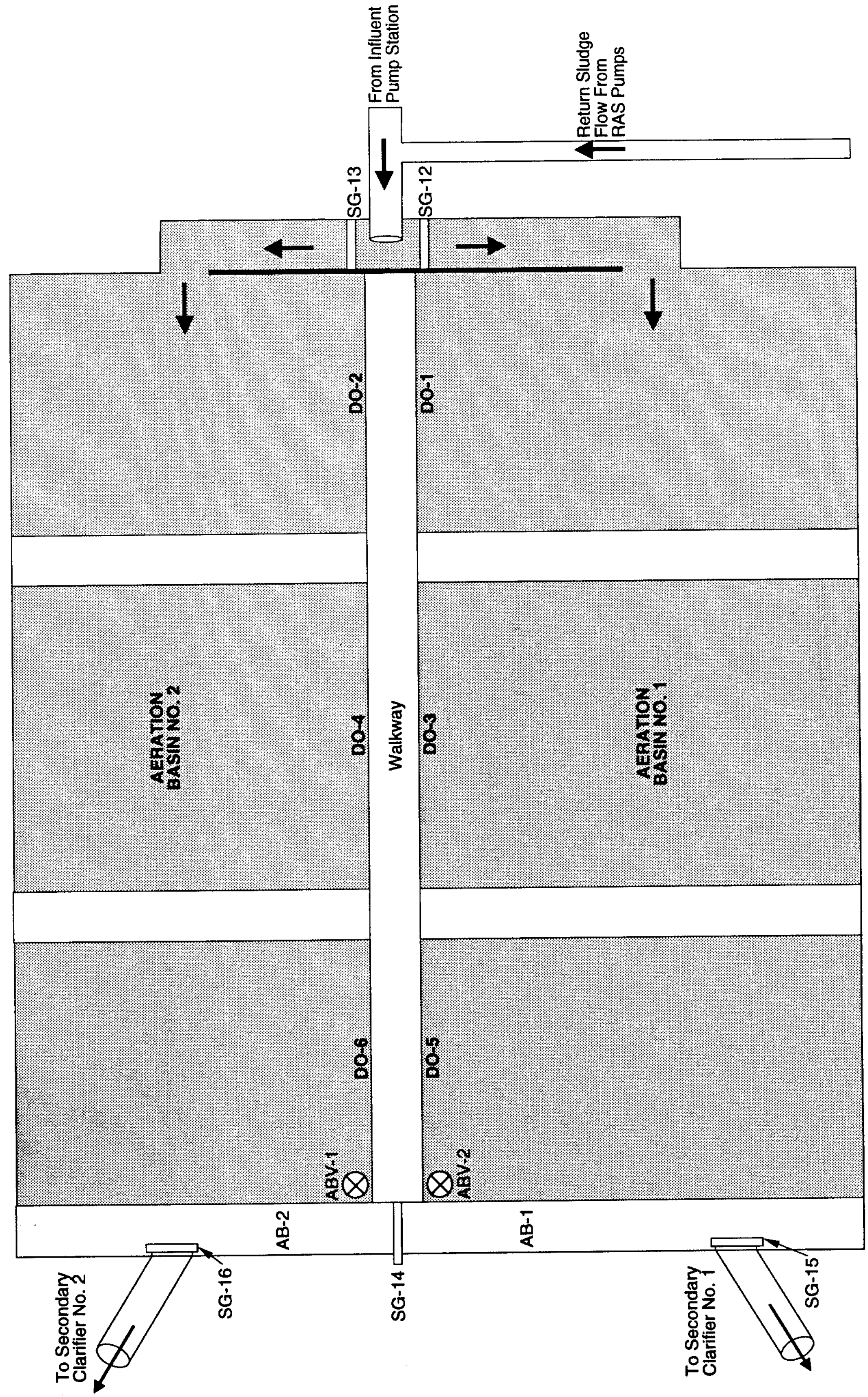

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Figure 8.4

HOWARD AIR FORCE BASE WWTP
SECONDARY CLARIFIERS / SLUDGE PUMPING STATION

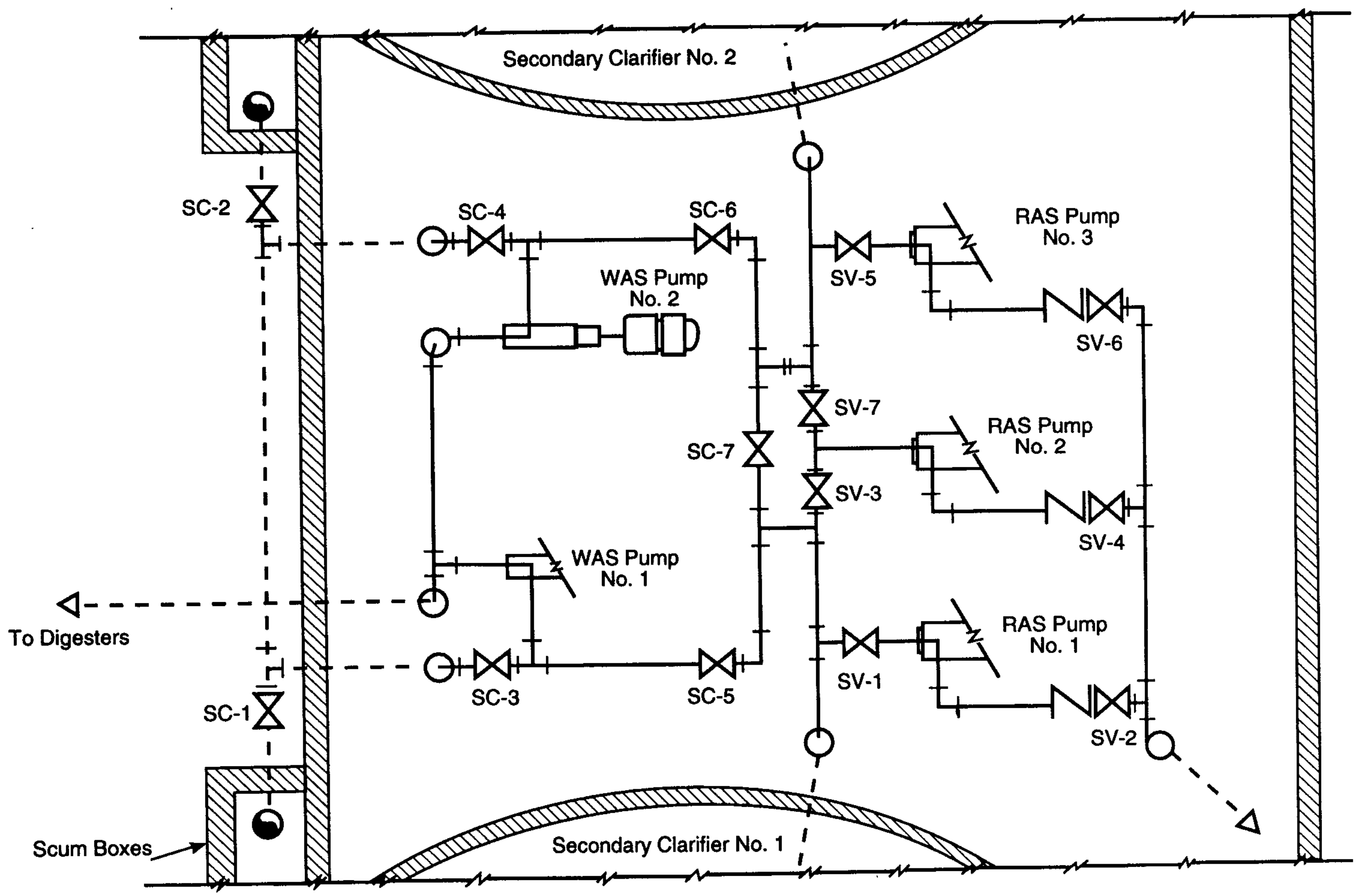

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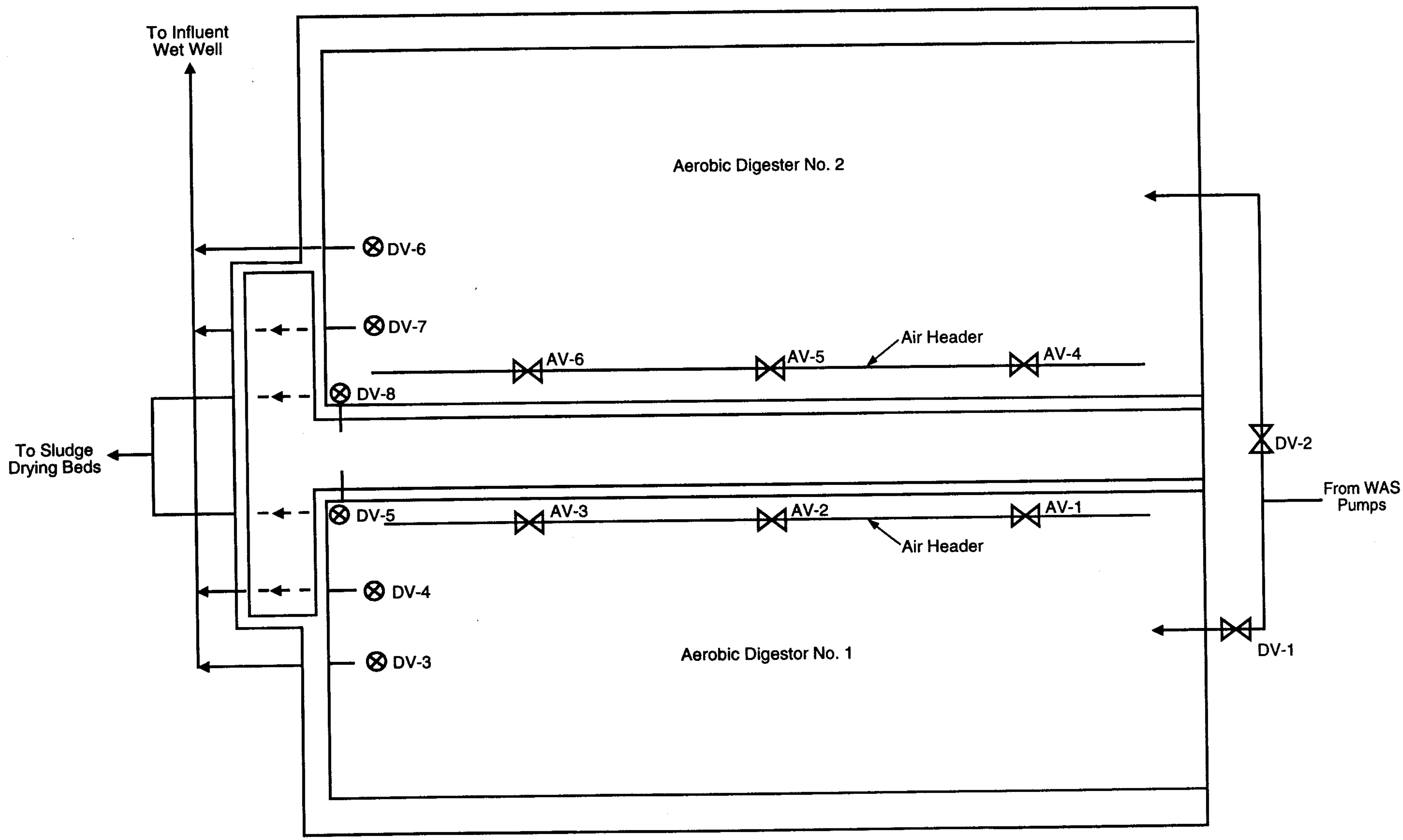
Figure 8.5

HOWARD AIR FORCE BASE WWTP
AEROBIC DIGESTERS



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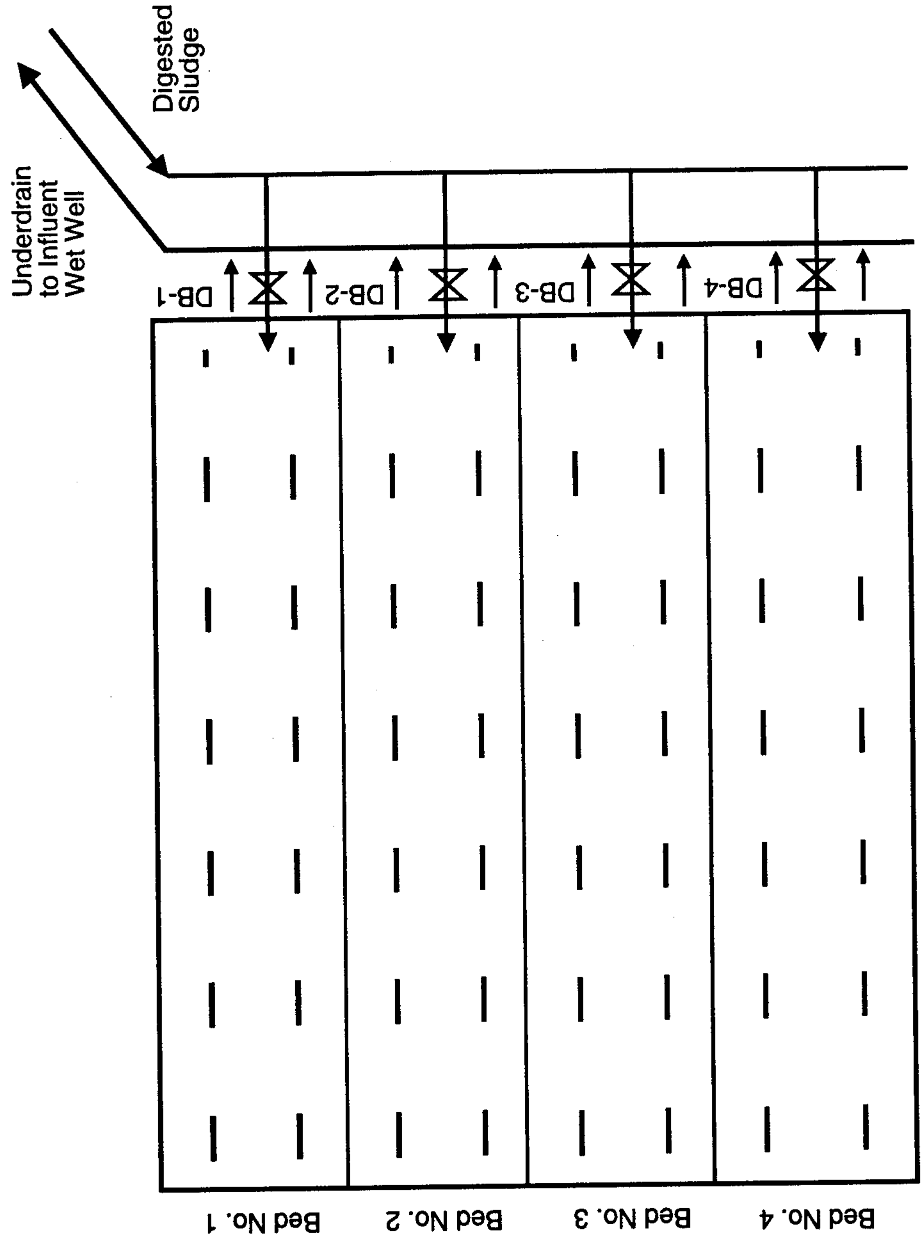
HOWARD AIR FORCE BASE WWTP
SLUDGE DRYING BEDS



G/721012/DG-…/0394

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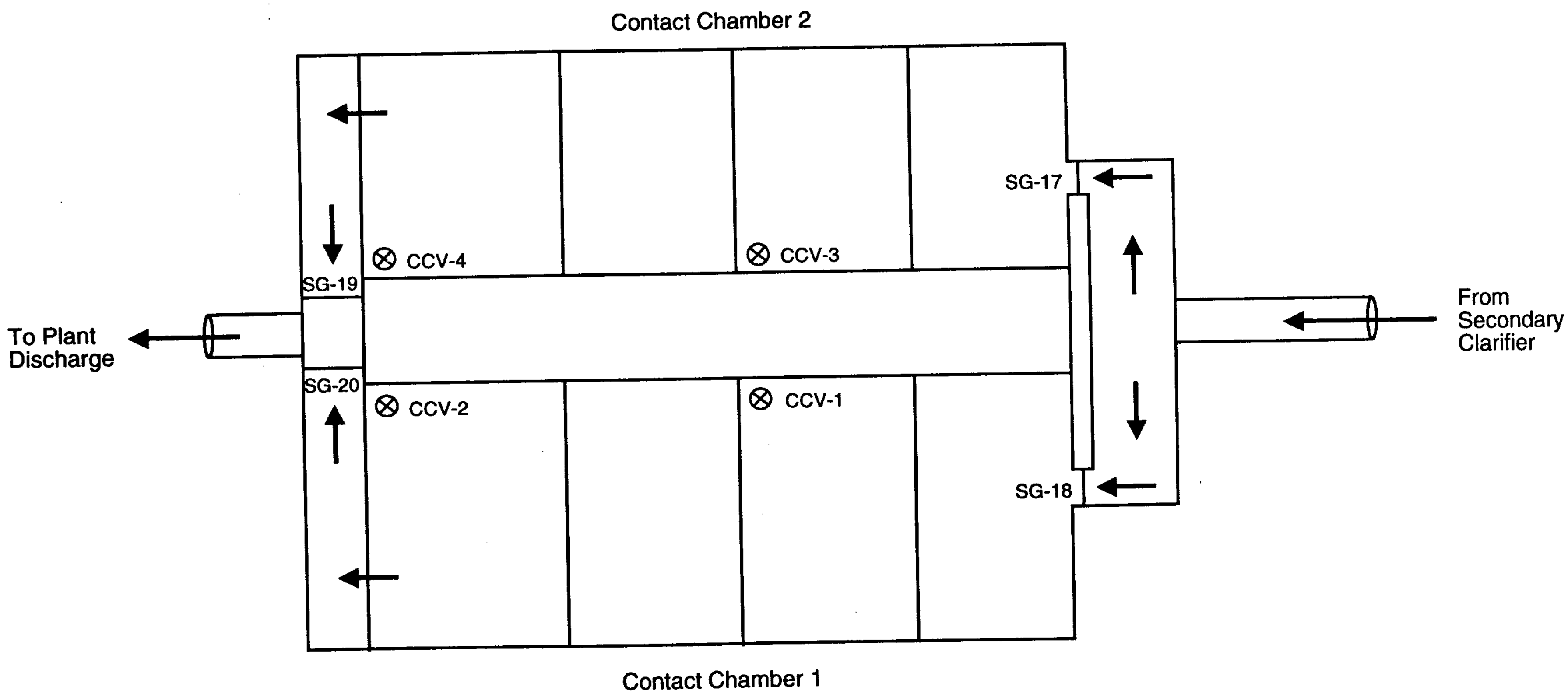
Figure 8.7

HOWARD AIR FORCE BASE WWTP
CHLORINE CONTACT CHAMBERS



G/721012/DG-4/GD/0394

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8.2 GENERAL STANDARDS OF PERFORMANCE

In addition to the Standard Operating Procedures contained in Tables 8.1 through 8.6, the treatment plant operators should adhere to the following general standards of performance:

1. All incoming operators should confer with the operators on the previous shift. Special consideration should be given to operational changes made, equipment malfunctions, and out of the ordinary conditions. The incoming operator will read the Operation Log for current operating conditions.
2. The incoming operators should immediately tour the treatment plant, observing all treatment equipment and processes.
3. Plant operators should maintain all records and logs current, neat and in ink. Unusual occurrences should be recorded in red ink to insure proper notice by all personnel.
4. Plant operators should perform all required equipment adjustments, lubrication and packing adjustments.
5. The operators should accomplish all sampling, analyses, pumping and preventive maintenance as scheduled.
6. The operators should perform all necessary housekeeping to keep all areas neat and clean to enhance resource protection and safety.
7. The plant operators must report all unusual conditions to the water and wastewater supervisor and the oncoming operator.
8. The plant operators must observe pertinent safety rules and regulations at all times.

TABLE 8.1
STANDARD OPERATING PROCEDURE
PRELIMINARY TREATMENT STRUCTURES

Procedure Step	Operator Checkoff
Normal Operation - Comminutor/Grit Chamber	
1. Observe the influent flow stream for unusual color, odors, floating solids, and oil and grease.	______
2. Observe operation of the comminuter. Note unusual noise, vibration, or heat buildup at the unit.	______
3. Observe the flow pattern and depth of flow through the Parshall Flume and the operation of the influent flow meter to ensure its proper functioning.	______
4. Slide gate settings for normal operations are as follows: OPEN: SG-1, SG-4, SG-6, SG-8, SG-11 CLOSED: SG-2, SG-3, SG-5, SG-7, SG-9, SG-10	______
5. Slide gate settings for alternate operation when bypassing comminutor/Parshall Flume channel are as follows: OPEN: SG-2, SG-5, SG-7, SG-8, SG-11 CLOSED: SG-1, SG-3, SG-4, SG-6, SG-9, SG-10	______
6. To bypass the grit chamber, close SG-8 and open SG-9 and SG-10.	______
7. Collect samples as required. See Chapter 4, Sampling Schedule.	______
8. Perform required preventive maintenance. Refer to Table 7.8.	______
To Remove Grit To the Grit Collection Box	
1. Start grit screw collector by pushing start button.	______
2. Observe grit screw operation ensuring proper grit dewatering and transfer.	______

TABLE 8.1 (continued)
STANDARD OPERATING PROCEDURE
PRELIMINARY TREATMENT STRUCTURES

Procedure Step	Operator Checkoff
3. Turn grit screw off when solids thin out. Make note of on-time of grit screw.	________
4. Observe dewatered grit for excessive organic material.	________
5. Record estimated grit volume removed.	________
<u>To Drain Grit Chamber</u>	
1. Bypass aerated grit chamber as described above.	________
2. Activate grit screw to remove as much grit as possible from grit hopper to the grit collection box.	________
3. Dewater the grit chamber completely using portable pumping equipment to pump wastewater to influent pump station wet well.	________
4. Perform inspection and required preventive maintenance. Refer to Table 7.9 and 7.10.	________

Note: Refer to Figure 8.1 for valve/equipment diagrams.

TABLE 8.2
STANDARD OPERATING PROCEDURE
INFLUENT PUMP STATION

Procedure Step	Operator Checkoff
Normal Operation	
1. Knife KG-1 and KG-2 should be open.	______
2. Plug valve PV-1 and PV-2 should be open.	______
3. The influent pumps operate automatically off wet well level. Observe operation of the pumps as they run through an on-off cycle. Observe the next cycle to ensure they are alternating properly.	______
4. Check the pumps for unusual heat, noise or vibration.	______
5. Ensure adequate seal water supply pressure to pumps.	______
6. Perform required preventive maintenance. Refer to Table 7.11.	______
To Remove Pump No. 1 from Service	
1. Turn pump motor controls to off position.	______
2. Isolate pump by closing knife gate KG-1 and plug valve PV-1.	______
3. Before working on pump, lock out and tag out the power switches.	______
4. Turn off seal water to pump.	______
5. Perform required maintenance and repairs. Refer to Table 7.11.	______
To Remove Pump No. 2 from Service	
1. Turn pump motor controls to off position.	______
2. Isolate pump by closing knife gate KG-2 and plug valve PV-1.	______
3. Before working on pump, lock out and tag out the power switches.	______
4. Turn off seal water to pump.	______
5. Perform required maintenance and repairs. Refer to Table 7.11	______

Note: Refer to Figure 8.2 for valve/equipment diagram.

TABLE 8.3
STANDARD OPERATING PROCEDURE
AERATION BASINS

Procedure Step	Operator Checkoff
Normal Operation	
1. Ensure the correct slide gate positions: OPEN: SG-12, SG-13, SG-15, SG-16 CLOSE: SG-14	________
2. Observe the pattern and role of aeration in each section of the aeration basins for uniformity and consistency.	________
3. Observe the aeration basin contents (mixed liquor). Note the color, odor and the type and color of surface foam.	________
4. Run dissolved oxygen tests at the following locations daily as a minimum: DO-1, DO-2, DO-3, DO-4, DO-5, DO-6	________
5. Run dissolved oxygen at locations DO-1 and DO-2 on each shift as a minimum.	________
6. Adjust air flow using the air adjustment butterfly valves in the blower house to maintain a dissolved oxygen of at least 2.0 mg/l at all DO locations.	________
7. On a monthly basis, run a complete dissolved oxygen profile on the aeration basins as a minimum.	________
8. Collect samples at locations AB-1 and AB-2 for mixed liquor suspended solid MLSS, mixed liquor volatile suspended solids (MLVSS) and 30 minute settleable solids each day.	________
9. Utilize MLSS andMLVSS data to analyze process parameters such as food to microorganism ratio (F/M), and sludge retention time (SRT) and to make appropriate process adjustments each day. Process data should be plotted on trend charts.	________
10. Perform the required preventive maintenance on the aeration basins. Refer to Tables 7.12 and 7.17.	________

TABLE 8.3 (continued)
STANDARD OPERATING PROCEDURE
AERATION BASINS

Procedure Step	Operator Checkoff
<u>To Shut Down Aeration Basin No. 1</u>	
1. Ensure all slide gates are in the correct position.	____________
OPEN: SG-13, SG-14, SG-16 — CLOSED: SG-12, SG-15	____________
2. Monitor as in normal operation except increase the frequency of D.O. measurements to twice per shift at location D0-2, DO-4 and DO-6.	____________
3. Make frequent air adjustments with the air adjustment butterfly valves in the blower house to offset the additional load on Basin No. 2.	____________
4. Open Aeration Basin No. 1 valve (ABV-1) and slowly drain contents to influent pump station wet well.	____________
<u>To Shutdown Aeration Basin No. 2</u>	
1. Ensure all slide gates are in correct position.	____________
OPEN: SG-12, SG-14, SG-15, SG-16 — CLOSED: SG-13	____________
2. Monitor as in normal operation except increase the frequency of D.O. monitoring to twice per shift at locations DO-1, DO-3 and DO-5.	____________
3. Make frequent air adjustments with the air adjustment butterfly valves in the blower house to offset the additional loading on Basin No. 1	____________
4. Open Aeration Basin No. 2 (ABV-2) and slowly drain contents to influent pump station wet well.	

Note: Refer to Figure 8.3 for valve/equipment diagrams of the aeration basins.

TABLE 8.4
STANDARD OPERATING PROCEDURE
SECONDARY CLARIFIERS

Procedure Step	Operator Checkoff
Normal Operations	
1. Ensure the following gates at the aeration basins are open:	________
SG-15 SG-16	________
2. Observe operation of the secondary clarifier drive units. Look for accumulations and check for unusual noises, vibrations or abnormal operating temperatures of bearings and motor.	________
3. Observe surface of clarifier for unusual accumulation of foam. Record observations and correlate to aeration basin operating conditions.	________
4. Perform sludge blanket depth measurements using the sludge judge twice per shift as a minimum. Use data to adjust RAS pumping rates.	________
5. Perform D.O. measurements on clarifier effluent daily.	________
6. Collect samples as required. See Chapter 4, Sampling Schedule.	________
7. Perform required preventive maintenance. Refer to Table 7.13.	________
Remove Secondary Clarifier No. 1 from Service	
1. Close Slide Gate SG-15 and and open SG-14.	________
2. Open secondary drain valves in yard adjacent to unit. Drain clarifier to influent pump station wet well. Pump clarifier contents to aeration basins.	________
3. Hose down clarifier when dewatered to remove sludge and scum deposits.	________
4. Perform required inspections, repair and maintenance. Refer to table 7.13.	________
5. Resume flow into clarifier by closing secondary drain valve and opening Slide Gate-15	________
Remove Secondary Clarifier No. 2 from Service	________
1. Close Slide Gate S-16.	________

TABLE 8.4 (continued)
STANDARD OPERATING PROCEDURE
SECONDARY CLARIFIERS

Procedure Step	Operator Checkoff
2. Open secondary drain valve in yard adjacent to unit. Drain clarifier to influent pump station wet well. Pump clarifier contents to aeration basins.	______
3. Hose down clarifier when dewatered to remove sludge and scum deposits.	______
4. Perform required inspections, repairs and maintenance. Refer to Table 7.13.	______
5. Resume flow into clarifier by closing secondary drain valve and opening Gate S-16.	______
<u>Returning Secondary Sludge To Aeration Basins</u>	______
1. Ensure that the appropriate suction and discharge valves are open, depending on the RAS pumps in service. Pump No. 1 is normally dedicated to Clarifier No. 1 and Pump No. 2 for Clarifier 2.	______
<u>RAS PUMP NO.1</u>: SV-1, SV-2 <u>RAS PUMP NO. 3</u>: SV-5, SV-6	______
2. To use RAS Pump No. 2, ensure SV-4 is open and either SV-3 or SV-7, depending upon which clarifier is being drawn from.	______
3. Observe clarifier conditions, sludge blanket depth and settleability data to adjust RAS pump variable speed controls throughout each shift.	______
4. Maintain sludge blanket depths at a minimum, but no greater than one fourth the tank side water depth.	______
5. Observe operation of RAS Pumps for excessive noise, heat or vibration	______
6. Collect RAS samples as required. Refer to Chapter 4, Sampling Schedule.	______
7. Perform preventive maintenance on RAS pumps. Refer to Tables 7.14 and 7.15.	______
<u>Wasting Sludge to Digesters</u>	
1. Ensure the following suction and discharge valves are opened.	______

TABLE 8.4 (continued)
STANDARD OPERATING PROCEDURE
SECONDARY CLARIFIERS

Procedure Step	Operator Checkoff
WAS PUMP NO.1: SC-3, SC-5 — WAS PUMP NO. 2: SC-4, SC-6	______
2. Header Valve SC-7 normally remains closed unless using WAS Pump No.1 for wasting from clarifier No. 2 or using WAS Pump No. 2 for wasting from Clarifier No. 1.	______
3. Calculate WAS Pump run time to waste the desired sludge volume.	______
4. Ensure the appropriate digester inlet valve is open.	______
FOR DIGESTER NO. 1: DV-1 — FOR DIGESTER NO. 2: DV-2	______
5. Activate WAS Pump and run for calculated run time.	______
6. Shut down WAS Pump.	______
7. Collect samples as required. Refer to Chapter 4, Sampling Schedule.	______
8. Perform required preventive maintenance on WAS Pumps. Refer to Tables 7.14 and 7.15.	______
Pumping Clarifier Scum To Digesters	______
1. Ensure the following suction and discharge valves are open: WAS PUMP NO. 1: SC-1, SC-3 — WAS PUMP NO. 2: SC-2, SC-4	______
2. Ensure sludge suction side valves are closed: SC-5, SC-6	______
3. Ensure that the appropriate digester inlet valve is open: FOR DIGESTER NO. 1: DV-1 — FOR DIGESTER NO. 2: DV-2	______
4. Activate WAS Pump, pump until clarifier scum box is emptied.	______
5. Perform required preventive maintenance on WAS Pumps. Refer to Tables 7.14 and 7.15.	

Note: Refer to Figures 8.3, 8.4 and 8.5 for valve/equipment diagrams.

TABLE 8.5
STANDARD OPERATING PROCEDURES
AEROBIC DIGESTERS

Procedure Step	Operator checkoff
Normal Operation	
1. Observe digesters aeration patterns for uniformity and consistency.	______
2. Observe digesters for any unusual color or odors, accumulation of foam or scum, and air leak noises.	______
3. Take dissolved oxygen (DO) measurement in each unit daily to ensure DO is 2.0 mg/l or greater.	
4. Adjust aeration rates to control DO using air control valves as follows:	______
For Digester No. 1 / For Digester No. 2 AV-1 / AV-4 AV-2 / AV-5 AV-3 / AV06	______
5. Collect samples as required. Refer to Chapter 4, Sampling Schedule.	______
6. Perform preventive maintenance. Refer to Tables 7.12 and 7.18.	______
To Draw Supernatant From Digester	
1. Discontinue feed to the digester by closing the appropriate inlet valve. For Digester No. 1 / For Digester No. 2 DV-1 / DV-2	______
2. Discontinue aeration of the digester for 6-12 hours by closing the appropriate air control valves. For Digester No. 1 / For Digester No. 2 AV-1 / AV-4 AV-2 / AV-5 AV-3 / AV-6	______
3. Open supernatant valve allowing flow from digester to influent wet well. For Digester No. 1 / For Digester No. 2 DV-3 / DV-6	______
4. Collect supernatant sample and analyze for BOD, TSS and VSS to assess loading impact on WWTP.	______

**TABLE 8.5 (Continued)
STANDARD OPERATING PROCEDURES
AEROBIC DIGESTERS**

Procedure Step	Operator checkoff
5. Shut supernatant valve and resume normal operation.	________
<u>To Draw Sludge To Drying Beds</u>	
1. Digester feed should be discontinued to unit being drawn from for 2-3 days prior to drawing sludge.	________
2. Digester aeration should be discontinued for 6-12 hours to allow settling and thickening of sludge prior to drawing sludge. Close the appropriate air control valves.	________
<u>For Digester No. 1</u>: AV-1, AV-2, AV-3 — <u>For Digester No. 2</u>: AV-4, AV-5, AV-6	________
3. Open the appropriate digester floor box valve to pull sludge into the drying bed header line. <u>For Digester No. 1</u>: DV-5 — <u>For Digester No. 2</u>: DV-8	________
4. Slowly open the appropriate sludge inlet valve at the drying beds. <u>Bed No. 1</u>: DB-1 — <u>Bed No. 2</u>: DB-2 — <u>Bed No. 3</u>: DB-3 — <u>Bed No. 4</u>: DB-4	________
5. Draw sludge to no more than 8-12 inches in depth in any bed.	________
6. Collect sample of digested sludge after sludge has been flowing for 5-10 minutes. See Chapter 4, Sample Schedule.	________
7. Close digester floor box valve and allow sludge to drain header line.	________
8. Close sludge inlet valve at drying beds.	________

TABLE 8.5 (Continued)
STANDARD OPERATING PROCEDURES
AEROBIC DIGESTERS

Procedure Step	Operator checkoff
<u>To Remove Digesters From Service</u>	
1. Block the appropriate feed line into the digester and discontinue feed as discussed above. Digester No. 1: DV-1 — Digester No. 2: DV-2	________
2. Turn off air to digester as discussed above and allow settling/thickening.	________
3. Draw as much sludge as possible from digester to drying beds as outlined in previous discussion.	________
4. Slowly drain the remainder of sludge to influent wet well by opening appropriate drain valve. This should be done over a 2-3 day period if possible to avoid overloading or shocking the plant. For Digester No. 1: DV-4 — For Digester No.2: DV-7	________
5. Wash down all interior equipment in digester and perform complete inspection of interior.	________
6. Perform required preventive maintenance. Refer to Table 7.12 and 7.18.	________

Note: Refer to Figure 8.5 and 8.6 for valve/equipment diagrams.

TABLE 8.6
STANDARD OPERATING PROCEDURES
CHLORINATION

Procedure Step	Operator Checkoff
<u>Normal Operation</u>	
1. Check chlorination system during each shift. Ensure correct feed rate at rotometer.	______
2. Check for chlorine leaks at chlorinator and cylinder connections.	______
3. Record the chlorine cylinder weight daily.	______
4. Check chlorine residual at the effluent of the chlorine contact basin hourly. Make feed rate adjustments to maintain chlorine residual of 0.5 - 1.0 mg/l for adequate disinfection.	______
5. Ensure that all slide gates are in the open position. SG-17 SG-19 SG-18 SG-20	______
6. Collect effluent samples as required, refer to Chapter 4, Sampling and Analytical Schedule.	______
7. Perform required preventive maintenance. Refer to Table 7.16.	______
<u>To Remove A Chlorine Contact Chamber From Service</u>	
1. To remove a contact chamber from service, close the appropriate inlet and outlet slide gates. <u>For Chamber No. 1</u> <u>For Chamber No. 2</u> SG-18 SG-17 SG-20 SG-19	______
2. Slowly open the appropriate drain valves and bleed the contact chamber contents to the influent wet well. <u>For Chamber No. 1</u> <u>For Chamber No. 2</u> CCV-1 CCV-3 CCV-2 CCV-4	______
3. Wash down and clean out the interior of the contact chamber, perform maintenance and repairs as needed.	______
4. Monitor the system as per items under normal conditions.	______
5. To place chamber back in service, open slide gates.	______

CHAPTER 9
RECORDS AND REPORTING

CHAPTER 9
RECORDS AND REPORTING

9.1 RECORDS AND REPORTING

A comprehensive record-keeping system is essential to the operation of the Howard AFB wastewater treatment plant. Daily operating records are the central component of any record-keeping system.

9.1.1 Daily Operating Logs

Daily observation of all components in the WWTP system is necessary to ensure continued successful operation. The operators should utilize both a journal type logbook and a plant operational log. An operational log has been developed specifically for the Howard WWTP and is included in this O&M Manual as Appendix C.

The plant operational log will contain routine information that is entered by each shift. All shifts are responsible for checking off and recording the following data:

- Plant Headworks
- Aeration basin conditions
- Secondary clarifier operating conditions
- Sludge pumped to digester
- Supernatant withdrawn from digester
- Personnel on duty
- Equipment problems and unusual operating conditions

9.1.2 Monthly Operating Logs

The wastewater treatment plant operators are required to prepare monthly operating logs, specifically Air Force forms 1462, Water Pollution Control Utility Operating Log (General) and 1463 Water Pollution Control Plant Operating Log (Supplementary). Information required for these form is drawn from daily plant operating logs and

laboratory data sheets. In addition, the plant is developing a detailed process control data format which will utilize a computer spread-sheet. All relevant process control data will be kept on this form for use in analyzing plant trends. Plots of key process parameters such as SRT, effluent TSS, MLVSS, F/M, etc. can be analyzed and graphically displayed to enhance process control.

9.1.3 Monthly Reports to Regulatory Agencies

Under Air Force requirements the WWTP operators are required to generate monthly self-monitoring reports. Data from the reports is entered on the Discharge Monitoring Report by the NCOIC or the Assistant Foreman of the wastewater treatment plant. The reports are then submitted to the Base Civil Engineer for review and approval.

9.1.4 Laboratory Worksheets

General laboratory protocol requires that specific laboratory records (bench sheets) be maintained as part of the WWTP's self monitoring program. These records provide the basis and validity for all data produced and reported. Examples of laboratory worksheets are provided in Appendix A. These worksheets should be periodically updated to reflect regulatory changes.

9.1.5 Sludge Disposal Records

A record of the quantity of sludge disposed of should be maintained for operational documentation. Generally, the quantity of sludge produced by the wastewater treatment plant should be equal to the quantity disposed of. A sludge disposal record form is included in Appendix D.

CHAPTER 10
NONDOMESTIC DISCHARGES

CHAPTER 10
NONDOMESTIC DISCHARGES

10.1 NONDOMESTIC DISCHARGES

In addition to the domestic wastewater treated at the Howard AFB WWTP, a number of nondomestic discharges contribute to the load on the plant. Results of a Hazardous Waste Management Survey Report prepared in July 1993 identified a number of sites where industrial waste could emanate and have an adverse impact on the wastewater treatment plant.

10.1.1 Sources of Nondomestic Discharges

Based on a review of the Hazardous Waste Management Survey Report prepared by Radian Corporation (July 1993) and subsequent site inspections, eight potential non-domestic wastewater sources were identified at the Base which could have an impact on the WWTP:

- 24th CES Sheet Metal/Welding Shop, Bldg. 4
- 24th Pavements, Equipment and Grounds, Bldg. 11
- Hangar #4, Bldg. 253
- Electro/Environmental Shop, Bldg. 256
- AAFES Service Station, Bldg. 700
- 24 SG/MWR Auto Hobby Shop, Bldg. 722
- Air Intelligence Squadron, Bldg. 723
- Hangar #1, Bldg. 236

A brief description of the operations and the wastewater generated at each facility is presented below.

The Sheet Metal Shop (Bldg. 4) uses an oil-base solution for the band saws and cutting shears. Presently, all wastewaters are discharged to the sewer without pretreatment.

The Pavements, Equipment and Grounds Shop generates and turns in approximately 110 gallons per year of waste oil, which is disposed of through a waste oil contractor.

The vehicles are washed at the wash rack located next to Building 11. Wash waters drain to an oil/water separator prior to their discharge to the sanitary sewer.

Lockheed operates a Corrosion Control Facility just outside Hangar #4. Painting and corrosion control activities for aircraft parts generate approximately 200 gallons of waste paint and related material. Wastewater generated at this facility is discharged directly to the sanitary sewer.

The Electro/Environmental Shop (Bldg. 256) is dedicated to servicing batteries. Small amounts of sulfuric acid solution (37%) are sometimes spilled when servicing batteries. The spilled solution is neutralized with sodium bicarbonate (baking soda) before it is flushed down the drain. All other battery wastes are disposed of by a hazardous waste contractor.

The AAFES Service Station performs minor maintenance on privately owned vehicles. This facility is provided with an oil/water separator to treat all wash waters generated in the maintenance operations. The separated oil flows into an underground storage tank, while the water is discharged to the storm sewer.

The Base Auto Hobby Shop is a recreational auto repair facility for privately owned vehicles. An oil/water separator intercepts the oily wastes generated by washing operations (e.g., garage floors and wash rack). The pretreated waste is discharged to the sanitary sewer.

The Air Intelligence Squadron Photographic Lab (Bldg. 723) develops various type of film, both black and white and color. Silver from the fixer photo processing solution is presently recovered using Clayton-type filters. The spent fixer is then discharged to the sewer. The used developer is mixed with large amounts of water and flushed down the drain. Although the amount of liquid developer system cleaner used annually is low (approximately 48.5 gal/yr), this product is a source of chromium and is being discharged directly to the sewer. Also, cyanide is often a by product of photographic development and can have a inhibitory or toxic impact on the WWTP. The presence of cyanide should be further investigated and should be analyzed for semiannually in the WWTP influent, effluent and sludge.

Hangar #1 houses the U.S. Navy LOG DET Operations, and also has been designated as a hazardous wastes accumulation point. The accumulation point routinely contains paint waste (e.g., mixture of paint and paint thinners), waste oils and hydraulic fluids. All wash waters generated in this facility are discharged to the sanitary sewer.

Although there appears to be some potential problems with industrial waste entering the sanitary sewer system, no definitive conclusions can be reached with regard to impact by industrial wastewater on the WWTP. No data on influent, effluent and sludge for metals and organic priority pollutants exists at present. To further evaluate this situation the plant influent, effluent and sludge should be sampled and analyzed semiannually for metals and organics analyses.

10.1.2 Importance of Pretreatment Programs for Nondomestic Discharges

Pretreatment is any operation or series of operations that change the characteristics of a nondomestic discharge to make it more acceptable for subsequent treatment and disposal at a wastewater treatment facility. Pretreatment programs are often necessary when nondomestic discharges contain toxic materials or other substances which could adversely affect the WWTP. Most WWTPs designed to treat domestic waste are incapable of treating toxic or concentrated nondomestic discharges. The result is that untreated nondomestic discharges may be incompatible with the WWTP.

Within a treatment plant, incompatibility may create four specific types of problems:

- Inhibition or interference with normal plant operations.
- Accumulation of heavy metals or other toxic substances.
- Pass through of organics and heavy metals.
- Undesirable effects on the sewer system or structures of the treatment plant.

The goal of any pretreatment program is to limit or eliminate problems associated with incompatibility in the WWTP. Reduction of incompatibility decreases the likelihood of plant upset and the discharge of pollutants to the environment.

The ramifications of not controlling nondomestic discharge are far-reaching. Toxic or incompatible discharge to the WWTP can lead to process upsets and violation of effluent standards. Further, the possibility of a buildup of contaminants in the sludge at

the WWTP could lead to increasingly higher costs for sludge disposal. Analytical costs associated with sludge disposal could also be increased.

10.1.3 Responsibilities for Nondomestic Pollutant Generators

The primary responsibility for monitoring the activities of nondomestic discharges is with Base Civil Engineering and Bio-Environmental Section. However, each facility manager must be constantly aware of activities in the facility that could lead to increased nondomestic discharges. Any dumps, leaks or uncontrolled discharges should be reported immediately to the WWTP personnel so they can take appropriate action.

APPENDIX A
EXAMPLE LABORATORY RECORDS, DATA SHEETS

BIOCHEMICAL OXYGEN DEMAND
STANDARD METHODS 18th EDITION, PAGE 5-2
PROCEDURE 5210B

SAMPLE/ DATE	VOLUME (ml) SAMPLE	VOLUME (ml) SEED	INITIAL			FINAL			D.O. DROP	BOD5 (mg/l)
			#	D.O.	DATE	#	D.O.	DATE		

G/AT663CTS/PM4/MAC/030392

FECAL COLIFORM
STANDARD METHODS, 18th EDITION, PAGE 9-60
MEMBRANE FILTER PROCEDURE 9222D

SAMPLE/ DATE	ML SAMPLE	PLATE COUNT	DILUTION FACTOR	NO./100ML	DATE/TIME SET UP	DATE/TIME READ	ANALYST

pH
STANDARD METHODS, 18th EDITION, PAGE 4-65
PROCEDURE 4500-H^+B

SAMPLE/ DATE	ZERO METER	BUFFER CHECK VALUE/READING/TEMP	DATE	SAMPLE READING/TEMP	ANALYST

SUSPENDED SOLIDS
STANDARD METHODS, 18th EDITION
(TOTAL SUSPENDED SOLIDS, PAGE 2-56, PROCEDURE 2540 D)
(VOLATILE AND FIXED SOLIDS, PAGE 2-57, PROCEDURE 2540E)

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Dish Residue Wt. (R)					
Dish Ignited Residue Wt. (I)					
Dish Wt. (T)					
Solids (grams) R-T					
Volatile Solids (grams) R-I					
Solids (mg/l)					
Volatile Solids (mg/l)					
Analyst/Date					

TOTAL SOLIDS
STANDARD METHODS, 18th EDITION
(TOTAL SOLIDS DRIED AT 103-105°C, PAGE 2-54, PROCEDURE 2540 B)
(VOLATILE AND FIXED SOLIDS IGNITED AT 550°C, PAGE 2-57, PROCEDURE 2540E)

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

Sample					
Sample Date					
Sample Volume (ml)					
Dish No.					
Weight of Dried Residue + Dish, mg (A)					
Weight of Dish & residue After Ignition, mg (B)					
Weight of Dish, mg (C)					
Total Solids, mg/l $= \frac{(A-C) \times 1000}{\text{Sample Volume, ml}}$					
Volatile Solids, mg/l $= \frac{(A-B) \times 1000}{\text{Sample Volume, ml}}$					

CHLORINE RESIDUAL SAMPLE

DATE COLLECTED	TIME ANALYZED	TYPE OF SAMPLE	Cl_2 PPM	LOCATION OF SAMPLE	INITIALS OF ANALYST

G/AT663CTS/PM4/MAC/030392

BOD$_5$ INCUBATOR RECORD

DATE READ	TIME READ	INCUBATOR TEMPERATURE O°C	INITIALS OF ANALYST	REMARKS

DRYING OVEN RECORD

DATE READ	TIME READ	TEMP. OF OVEN O°C	INITIAL OF ANALYST	FILTER DRYING START TIME	FILTER DRYING FINISH TIME	SAMPLE DRYING START TIME	SAMPLE DRYING FINISH TIME

LAB REFRIGERATOR RECORD

TEMP. OF REFRIGERATOR

DATE READ	TIME READ	TEMP. OF REFRIGERATOR	INITIALS OF ANALYST	REMARKS

G/AT663CTS/PM4/MAC/030392

DILUTION WATER INCUBATION RECORD

DATE READ	TIME READ	INCUBATOR TEMPERATURE O°C	INITIALS OF ANALYST	REMARKS

COMPOSITE SAMPLE RECORD

DATE COL-LECTED	BOTTLE NO.	TIME COL-LECTED	LOCATION OF SAMPLE	PARSHALL FLUME		MGD	% ERROR	FLOW METER READING	CHART RE-CORDER READING	COM-POSITE SAMPLE ML	SAMPLERS INITIALS
				INCH	FT.						

G/AT663CTS/PM4/MAC/030392

APPENDIX B
SUGGESTED MAINTENANCE
RECORD KEEPING FORMS

PUMP DATA

PUMP: ______________________ EQUIP. NO.: ______________

LOCATION: ______________________________________

MFGR.: ______________________ MODEL: ______________

SIZE: ______________________ TYPE: ______________

CAPACITY: ______________________________________

MATERIAL: ______________________________________

BEARING NOS.: ______________________________________

SEAL TYPE/SIZE: ______________________________________

SERIAL NO.: ______________ DATE INSTALLED: __________ COST: __________

LOCAL REP.: ______________________ PHONE: ______________

PUMP DATA CARD

MOTOR DATA

MOTOR: ______________________ EQUIP. NO.: ______________

MFGR.: ______________ MODEL: ______________

HORSEPOWER: ______________ SPEED: ______________

VOLTAGE: ______________ AMPS: ______________

PHASE: ______________ HERTZ: ______________

SERVICE FACTOR: ______________ AMB. TEMP.: ______________

INSULATION: ______________ TEMP. RISE: ______________

FRAME: ______________ ENCLOSURE: ______________

BEARING NO.: ______________________________

SERIAL NO.: ______________ DATE INSTALLED: ________ COST: ________

MOTOR DATA CARD

EQUIPMENT DATA

UNIT: ____________________ EQUIP. NO.: __________

LOCATION: ____________________________________

MFGR.: ______________ MODEL: ______________

SIZE: ______________ TYPE: ______________

RATING HP: ______________ CAPACITY: ______________

INPUT RPM: ______________ OUTPUT RPM: ______________

SERVICE FACTOR: ______________ RATIO: ______________

OTHER DESCRIPTION: ____________________________

____

BEARING NO.: __________________________________

SERIAL NO.: __________ DATE INSTALLED: __________ COST: __________

LOCAL REP.: ____________________ PHONE: __________

EQUIPMENT DATA CARD

EQUIP. NO.: ______

SERVICE RECORD - A

EQUIPMENT: ______

MANUFACTURER'S MANUAL: CONTRACT ______ VOL.: ______ SECTION: ______

TASK NO.	TASK DESCRIPTION	LUBE CODE	FREQUENCY OF SERVICE

SERVICE RECORD - A (INFORMATION)

ES ENGINEERING-SCIENCE

SERVICE RECORD - B

EQUIP. NO.: ______

EQUIPMENT: ______

TASK	DATE	INIT.	TIME	REMARKS	TASK	DATE	INIT.	TIME	REMARKS

SERVICE RECORD - B (DATA)

EQUIP. NO.: ____________

REPAIR RECORD

EQUIPMENT: ____________

MANUFACTURER'S MANUAL: CONTRACT ________ VOL.: ______ SECTION: ________

DATE	MAINTENANCE WORK REQUIRED AND PARTS REPLACED	REPLACEMENT PART		INIT.	TIME
		NUMBER	COST		HOURS

REPAIR RECORD CARD

ES ENGINEERING-SCIENCE

EQUIP. NO.: ______________

MOTOR SERVICE RECORD

PRIMARY EQUIPMENT: ______________ OVERLOAD RELAY ______ SIZE ______

MANUFACTURER: ______________ HEATER NO. ______ SETTING ______ C.T. AMPS ______

HP ______ VOLTS ______ AMPS ______ STARTER ______ TYPE ______ SIZE ______

PHASE ______ HZ. ______ COIL NO. ______ VOLTAGE ______ HZ. ______

TEST DATA

DATE OF TEST	MOTOR						STARTER	CONTACT		BEARING	BRUSHES	SLIP RING	INIT.	REMARKS
	VOLTAGE	AMPERES 1	2	3	MEGGER READING	TEMP		CK.	LUB.					

MOTOR SERVICE RECORD FORM

SPARE PARTS RECORD

Order		Item			Received		Issued			Number In Stock	Inventory Date & Initial
No.	Date	Quantity	Description	Cat. No.	Date	Cost	Date	Quantity	Index No.		

SPARE PARTS RECORD FORM

ES ENGINEERING-SCIENCE

SAMPLE INVENTORY CARD

STOREROOM INVENTORY CARD

Item No. ________

Isle No. ________

Bin No. ________

Item Description -

Quantity Maximum ____________ Minimum ____________

Reorder ____________

INVENTORY INFORMATION

Quantity Used or Stocked	Date	Signed	Quantity on Hand	USAGE OR SUPPLY INFORMATION Usage - Work Order No. Supply - Purchase Order No.

APPENDIX C
OPERATIONS LOG

PLANT OPERATION HOURLY RECORDS - HOWARD AFB - PANAMA

DATE

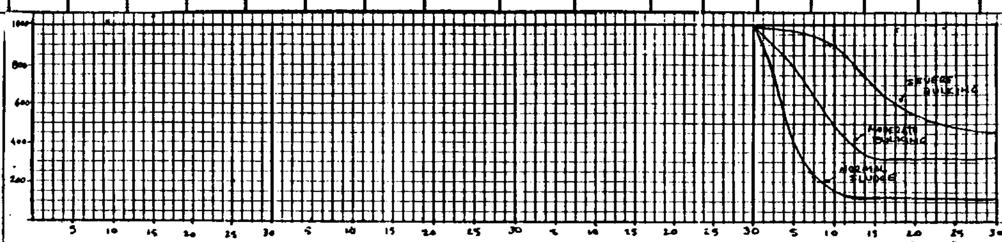
OPERATIONS RESPONSIBLE =

TIME	FLUME READ	1-2 BLOWER	RETURN PUMPS 1	RETURN PUMPS 2	RETURN PUMPS 3	RET. FLOW	SCUM BOXES	LINES FLUSH	WASTING 1 - 2 DIG.	SLUDGE LEVEL	CL2 RESIDUAL	DIGESTER INFORMATION 1 - 2	SHUT AIR OFF	START SUP.	STOP SUP.	PH	PLANT D.O.	STOR. TANK LEVEL	S.CH. INTLS.
0000																			
0100																			
0200																			
0300																			
0400																			
0500																			
0600																			
0700																			
0800																			
0900																			
1000																			
1100																			
1200																			
1300																			
1400																			
1500																			
1600																			
1700																			
1800																			
1900																			
2000																			
2100																			
2200																			
2300																			
TOTALS																			

	SHIFT LAB. RECORDS		HRS.	HRS.	HRS.	HRS.	HRS.	HRS.
DISSOLVED OXYGEN MG/LT	AERATION TANK PLANT #1	IN						
		MID						
		OUT						
	CLARIFIER #1							
	AERATION TANK PLANT #2	IN						
		MID						
		OUT						
	CLARIFIER #2							
	DIGESTER #1 (LEVEL)							
	DIGESTER #2(LEVEL)							
	FINAL EFFLUENT							

			HRS.	HRS.	HRS.	HRS.
SETTLEABILITY %	AERATION TANKS	PLANT #1				
		PLANT #2				
	AVERAGE AERATION TANKS					
	RETURN PUMPS SLUDGE	#1				
		#2				
		#3				
	AVERAGE RETURN PUMPS					

PLANT DATA			
FLOW TOTALIZER READING			
PREVIOUS READING			
TOTAL FLOW	MGD		
VOLUME OF AIR	SCFM		
VOLUME WASTED	MGD		
VOLUME RETURNED	MGD		
WASTE PUMPRATE	GPM		
WASTING SCHEDULE	MIN		
SCREENING	CU. FT.		
GRIT REMOVED	CU. FT.		
CHLORINE GAS WT.	LBS		
CHLORINE GAS PREVIOUS WT.	LBS		
CHLORINE GAS USED	LBS		
CALCIUM HYPOCHLORITE USED	LBS		
SODIUM HYPOCHLORITE USED	LBS		



HAFB FORM 61A, JUN 94 (EF)

WEEK LABORATORY REPORT

FROM | TO

	TEST		MON	TUES	WED	THUR	FRI	SAT	SUN
	TECHNICIAN INITIALS								
PH	PH INFLUENT								
PH	PH EFFLUENT								
T°	INFLUENT TEMPERATURE °F								
	RESIDUAL CHLORINE PPM								
DISSOLVED OXYGEN - PPM	AERATION TANKS PLANT #1	IN							
		MID							
		OUT							
	CLARIFIER #1								
	AERATION TANKS PLANT #2	IN							
		MID							
		OUT							
	CLARIFIER #2								
	DIGESTER PLANT #1 (LEV)								
	DIGESTER PLANT #2 (LEV)								
	FINAL EFFLUENT								
SETTLEABILITY	INFLUENT ML/L								
	EFFLUENT ML/L								
	PLANT #1 A.T. %								
	PLANT #2 A.T. %								
	AVERAGE A.T. %								
	RETURN #1 %								
	RETURN #2 %								
	RETURN #3 %								
	AVERAGE RETURN %								
SUSPENDED SOLIDS	GRAP	INFLUENT MG/LT							
		INFLUENT VOLATILE %							
		EFFLUENT MG/LT							
		EFFLUENT VOLATILE %							
		% OF REMOVAL (TOTAL)							
	COMP.	INFLUENT MG/LT							
		INFLUENT VOLATILE %							
		EFFLUENT MG/LT							
		EFFLUENT VOLATILE %							
		% OF REMOVAL (TOTAL)							
	AERATION TANK PLANT #1	MG/LT							
		VOLATILE %							
	AERATION TANK PLANT #2	MG/LT							
		VOLATILE %							
	AVARAGE AERATORS MG/LT								
	AVERAGE AERATORS VOLATILE %								
	RECIRCULATING PUMPS	#1 MG/LT							
		#1 VOLATILE %							
		#2 MG/LT							
		#2 VOLATILE %							
		#3 MG/LT							
		#3 VOLATILE %							
		AVERAGE MG/LT							
		AVERAGE %							
TOTAL SOLIDS	RETURN COMPOSITE SAMPLE	TOTAL %							
		VOLATILE %							
		FIXED %							
	DIGESTER (FULL) #1 OR #2	TOTAL %							
		VOLATILE %							
		FIXED %							
C.O.D.	INFLUENT MG/LT								
	EFFLUENT MG/LT								
	% OF REMOVAL %								
B.O.D.	INFLUENT MG/LT								
	EFFLUENT MG/LT								
	% OF REMOVAL %								
	MICROSCOPIC OBSERVATION								
	FECAL COLIFORM/100ML								
DATA	SVI								
	F/M RATIO								
	SRT (SLUDGE AGE)								

PREVIOUS 4 WEEK AVERAGE B.O.D.

PREVIOUS WEEK AVERAGE FLOW

PREVIOUS WEEK AVERAGE S.S.

INFLUENT	EFFLUENT

LAST 5 DAYS MLVSS (AV.)

DAY	A.T.	RETURN
MON		
TUES		
WED		
THUR		
FRI		
SAT		
SUN	SUN	

REMARKS

HAFB FORM 0-61 MAR 94 *(EF)*

APPENDIX D
SLUDGE DISPOSAL RECORD FORM

ELLSWORTH AFB WWTP
SLUDGE DISPOSAL RECORD

Date		
Drying Bed No.		
Volume of Sludge Pumped to Drying Bed		MG
Concentration of Sludge, Total Solids		mg/l
Percent Volatile Solids		%
Quantity of Sludge Disposed*		LBS

Date		
Drying Bed No.		
Volume of Sludge Pumped to Drying Bed		MG
Concentration of Sludge, Total Solids		mg/l
Percent Volatile Solids		%
Quantity of Sludge Disposed*		LBS

Date		
Drying Bed No.		
Volume of Sludge Pumped to Drying Bed		MG
Concentration of Sludge, Total Solids		mg/l
Percent Volatile Solids		%
Quantity of Sludge Disposed*		LBS

* LBS = MG(3) x mg/l(4) x 8.34

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